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SLEEP AND PREDICTED COGNITIVE PERFORMANCE OF NEW CADETS DURING CADET BASIC TRAINING AT THE UNITED STATES MILITARY ACADEMY

by

Daniel B. Miller

September 2005

Thesis Advisor: Nita Lewis Miller
Second Reader: Jeff Crowson

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SLEEP AND PREDICTED COGNITIVE PERFORMANCE OF NEW CADETS DURING CADET BASIC TRAINING AT THE UNITED STATES MILITARY ACADEMY

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The amount of sleep being received per day among New Cadets at West Point during Cadet Basic Training (CBT) was investigated. Sleep was measured using actigraphy on a stratified sample of 80 New Cadets. The results indicated that New Cadets slept an average of approximately 340 minutes or 5 hours, 40 minutes per night. The results were compared to self-reported survey data to determine whether sleep prior to arrival at West Point matched measured sleep at CBT. The findings indicate that the study population is sleep-deprived during CBT. The study population was sleeping on average 2 hours, 6 minutes less per night during CBT than prior to their arrival at West Point. The findings also indicate that the amount of sleep was not related to gender, race, cadet company assignment, age, recruited athlete status, or circadian chronotype (Morningness/Eveningness preference).

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EXECUTIVE SUMMARY

Military operations today are continuous in nature. Around-the-clock operations are the norm, rather than the exception. Sleep plans are talked about, but not often enforced in the heat of operations. The prevailing military culture even encourages such behavior, with contests among peers as to who is operating with the least sleep. The insidious nature of this competition is that it leads to leaders operating with reduced cognitive function, but without realizing just how impaired their decision-making and judgment has become. New Cadets at the United States Military Academy, West Point, New York, are given an immediate education in this aspect of the military life upon their entrance. The schedule at West Point is tough, demanding, and virtually unyielding. There are three official major competitors for a cadet's time and effort during matriculation at West Point; academic, military, and athletic.

This study is part of a four-year longitudinal study undertaken to assess the sleep hygiene of cadets at the United States Military Academy. Specifically, data on the Class of 2007 were collected over the course of Cadet Basic Training (CBT). Survey data (n=1290) were collected on the population's sleep habits prior to reporting to West Point. Actigraphy data (n=79) were then collected over the course of Cadet Basic Training, to include Reorganization Week, the week prior to the beginning of the Fall academic term. The survey was analyzed and included as part of a different thesis (Kenney & Neverosky, 2004), but the results were

compared with the actigraphy analysis. The actigraphy analysis showed no statistical significance when comparing the following categories: gender, circadian chronotype (morningness-eveningness preference), age, company by detail, race by detail, and recruited athlete by detail. Actigraphy data were imported in the Fatigue Avoidance Scheduling Tool (FAST), used to calculate predicted effectiveness for each individual. This FAST analysis showed that the New Cadet with the highest mean CBT sleep (6 hours, 38 minutes/night) operated at a mean of 91.19% effectiveness during waking hours. The median New Cadet (5 hours, 44 minutes/night) operated at 84.1% effectiveness during waking hours. The minimum New Cadet (4hours, 20 minutes/night), also a football recruit, achieved only 75.3% mean waking effectiveness. Adding an additional hour of sleep to cadet's schedules would result in a mean of 90.4% waking effectiveness for the median cadet while the the cadet with the minimum sleep would have a mean waking effectiveness of 83.4%. The extra 60 minutes of sleep is the difference between a cadet who is cognitively alert and learning during training, and a cadet who is cognitively impaired and has difficulty learning due to lack of sleep.

I. INTRODUCTION

A. OVERVIEW

Prior to the 21st Century, 24-hour military operations were rare. In general, armies moved and fought during daylight hours, and night operations were infrequent. The weapons systems in use were simply inadequate to the demands of accurately locating and engaging (with any real hope of success) the enemy at night. But as technological advances (particularly in artificial illumination) allowed limited military operations after dark, armies began to use the night in order to engage the enemy at closer ranges, in order to increase the accuracy and lethality of the attack. Night movements concealed friendly forces from observation by enemy assets (including aerial reconnaissance). By World War II, night operations had become commonplace. Today, 24-hour operations by military forces are ubiquitous, and only the foolhardy would assume that nightfall offers safety from attack.

Since there are only 24 hours in a day, constant operations require a sacrifice of other activities in order to fit night operations into the daily schedule. Frequently, the sacrifice is getting less sleep per night, especially among leaders. Many studies have investigated the degradation in cognitive performance experienced by humans with increasing amounts of sleep deprivation. (Lieberman, Tharion, Shukitt-Hale, Speckman, & Tully, 2002; Shay, 1998; Belenky, Wesensten, Thorne, Thomas, Sing, Redmond, Russo, & Balkin, 2003; Harrrison, & Horne, 2000) One especially dangerous effect of sleep deprivation is that sleep-deprived individuals often do not realize that

they are operating with decreased cognitive and physical capacities – such degraded performance has been found to be very similar to the deleterious effects of alcohol consumption (Williamson, Feyer, Mattick, Friswell, & Finlay-Brown, 2001).

While cadets at the United States Military Academy (USMA) are certainly a part of the military, they are rarely required to execute 24-hour operations. During Cadet Basic Training however, their time-management skills are put to an immediate and on-going test during their time at West Point.

Cadet Basic Training (CBT) begins on Reception Day (R-Day), usually in late June. The cadet candidates report to Eisenhower Hall, are given a short briefing (mostly for the benefit of accompanying family members), and are then given 90 seconds to say good-bye. They exit Eisenhower Hall to begin their lives as 'New Cadets', their designation throughout CBT. The first day includes uniform issue, training on how to stand, march, and behave like a New Cadet, and later that day, the New Cadets march in a full review that includes receiving the cadet oath.

The remaining six weeks include all of the training normally experienced by enlisted soldiers in Basic Training, along with additional demands required to succeed as a New Cadet. The transition is a difficult one, and it is not uncommon for New Cadets to drop out during CBT. As part of this transition, New Cadets must somehow succeed while receiving far less sleep than the vast majority of them are accustomed. They typically get far less sleep during CBT than the recommended 8.5 to 9.25 hours per night

for individuals in their late teens – early twenties (Carskadon, 1998).

This thesis is part of a four-year longitudinal study designed to assess the overall sleep hygiene of cadets attending USMA, and focuses only on sleep patterns during CBT in the summer of 2003.

B. PROBLEM AND PURPOSE

USMA has studied cadet sleep at various times and in various forms since at least the 1960s (Shattuck, 2003). However, much of these data were either anecdotal in nature or the result of self-reported surveys. Gathering accurate data using these methods is problematic, as you are forced to rely on the participant to recall how much sleep they received over a certain period of time. The challenge in the current study is to empirically assess how much sleep cadets actually get each night, and compare that with the 8.5 to 9.25 hours per night recommended for an adolescent population. This study used actigraphy to measure the amount of sleep that the study participants received each night. New Cadets were active during the entire day, so nap analysis was not an issue for this phase of the study.

The purpose of this study is to collect objective data to inform USMA leadership on modifications that will be made to CBT in order to improve sleep hygiene.

The focus of this longitudinal study is the USMA Class of 2007. Survey data of the entire class were acquired to capture the class’ sleep history for the 30 days prior to reporting to West Point. For the CBT portion of the study, actigraphy data were gathered on 79 New Cadet

participants. Whenever possible, the data were collected over the entire course of CBT.

C. APPROACH

During the initial phase of CBT, New Cadets (n = 1289) were administered a survey to determine their pre-reporting sleep habits. A portion of this survey included the Pittsburgh Sleep Quality Index (PSQI). The purpose of this survey was to assess sleep history of each Cadet in the 30 days prior to arrival at West Point. This survey also allowed the establishment of a baseline of average sleep duration for the study population prior to their arrival at West Point.

As a follow-on phase of the study, a stratified random sample of New Cadets (n = 78, was selected to gather objective activity levels during the study period. The sample was stratified on the basis of gender, ethnicity, athlete, and company. A wrist activity monitor (WAM) was issued to each of the 79 subjects, and were worn for virtually the entire duration of CBT and Reorganization Week. Reorganization Week occurs following the conclusion of CBT, and it is when the New Cadets are first accepted as full Cadets, along with joining their academic companies. Actigraph data were downloaded from each WAM and subsequently analyzed to determine sleep time during the recording period. The Fatigue Avoidance and Scheduling Tool (FAST) uses the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model, and is used by various government agencies to determine the predicted levels of human performance based on circadian rhythms, amount and quality of sleep, and combines cognitive performance

predictions based on the conditions experienced by the subject.

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II. LITERATURE REVIEW

A. OVERVIEW

This review focuses on the effects of sleep deprivation on human performance, and in particular how those effects impact adolescent sleep patterns. The review begins by describing the human sleep drive and circadian rhythm alertness levels, both of which are affected by the level of sleep deprivation. The fundamentals of sleep architecture in humans are also reviewed and discussed, to include how adolescent sleep patterns differ from those of adults. A particular focus of this literature review is sleep in human adolescents, which comprises the study population. The effects of sleep deprivation in humans, along with fatigue countermeasures are discussed. How lack of sleep affects the learning process along with the validity of actigraphy for sleep studies are also a part of the review. Models to measure and predict human fatigue and task performance effectiveness are the final part of the review.

B. SLEEP ARCHITECTURE

1. Circadian Rhythm and Human Sleep Drive

Sleep is a state marked by reduced levels of consciousness, relative inactivity of skeletal muscles, and decreased metabolism. Sleep is also a period in which a person is generally unresponsive to the environment. Humans, like all of the higher-order organisms require sleep, and sleep takes various forms for each animal (Horne, 1998). Sufficient sleep is a biological requirement, because sleep deprivation will lead to reduced

physical and psychological functioning, and in extreme forms can result in the individual's death (Rechtshcaffen, Bermann, & Everson, 1989). Debate continues on just how much sleep a human being needs per night to operate effectively, but generally accepted figures are eight hours for adults, and 8.5-9.25 hours for adolescents (Dement, 1999).

For humans, sleep typically occurs at night. This is because humans are diurnal creatures. Diurnal organisms are active during daylight hours, and this accurately describes typical human behavior. Artificial light allows humans to extend their activity into the night hours. The advent of electricity; providing much better lighting than gas- or oil-fired lamps, enabled shift-work over a 24-hour period (Carskadon & Dement, 2000).

For humans, hormones fluctuate throughout the course of a 24-hour period and regulate the sleep-wake cycle. The hypothalamus is the main regulator of the hormones that form the basis for the sleep-wake drive (Von Dongen & Dinges, 2003; Van Dongen, 2003). The body's "clock" is a portion of the hypothalamus known as the suprachiasmatic nucleus. The suprachiasmatic nucleus (SCN) consists of a pair of structures containing about 20,000 neurons (National Institute of Neurological Disorders and Stroke, 2004). The SCN is located immediately above the point where the optic nerves cross, and it receives signals from the optic nerves. The SCN is one component of the body's homeostatic control system, the system designed to keep the body's internal environment within "normal" limits.

In general, infants from three to four months of age are capable of sleeping for six to eight-hour periods.

That is a very fortunate thing for the sleep-deprived parents. By age five to six, the afternoon nap for children has disappeared, and at that point the human is a truly diurnal creature (Carskadon & Dement, 2000).

The SCN plays a crucial component in the cycle of an individual’s rhythm. The eye transfers light energy into electrical impulses. These signals are then received by the SCN via the optic nerves, thereby activating the SCN in response to daylight. The activation of the SCN results in other signals being sent to several regions of the brain. One of the primary recipients of these signals is the pineal gland. The pineal gland responds to activation by “switching off” the production of melatonin (Kitay, 1954). The hormone’s level of melatonin in the body increases after dark, resulting in an increase in sleepiness. Shutting down production of this hormone begins the body’s transition from sleep to wakefulness (Monk, 1990).

The overall effect of the homeostatic control system is the formation of a sinusoidal pattern of human alertness, better known as the circadian rhythm. Sleep plays an important role in this pattern allowing the body time to repair the stresses and strains induced as a naturally occurring part of daily activity. Additionally, sleep plays an important role in memory consolidation (Siegel, 2001) and task performance (Belenky, 1997; Schein, 1957).

Human activity conforms to the natural cycle of day and night, divided by humans into a 24-hour period. However, the natural circadian rhythm is actually a bit longer than the standard 24-hour day. In the absence of light or without temporal cues (clocks, watches, or

standard meal times), humans typically exhibit a cycle that is between 24.5 and 25 hours in length (Horne, 1988). These cues are known as ***zeitgebers***, a German word literally translated as "time-givers" (Webster's New World Medical Dictionary, 2003). Humans utilize such zeitgebers in order to synchronize our natural 24.5 to 25-hour body clock with the artificial 24-hour long day.

Fatigue and alertness in humans are natural antagonists, and there are any numbers of ways to assess both components throughout the course of the day. Reaction time tasks are one method to determine relative alertness, with decreasing alertness inversely related to reaction time. However, the RT-alertness is not a linear relationship, and reaction time is fastest with an intermediate alertness level (Broadbent, 1971; Welford, 1980). In general, fatigue and alertness are inversely related, and the more fatigued one is, the less alert one tends to be as well.

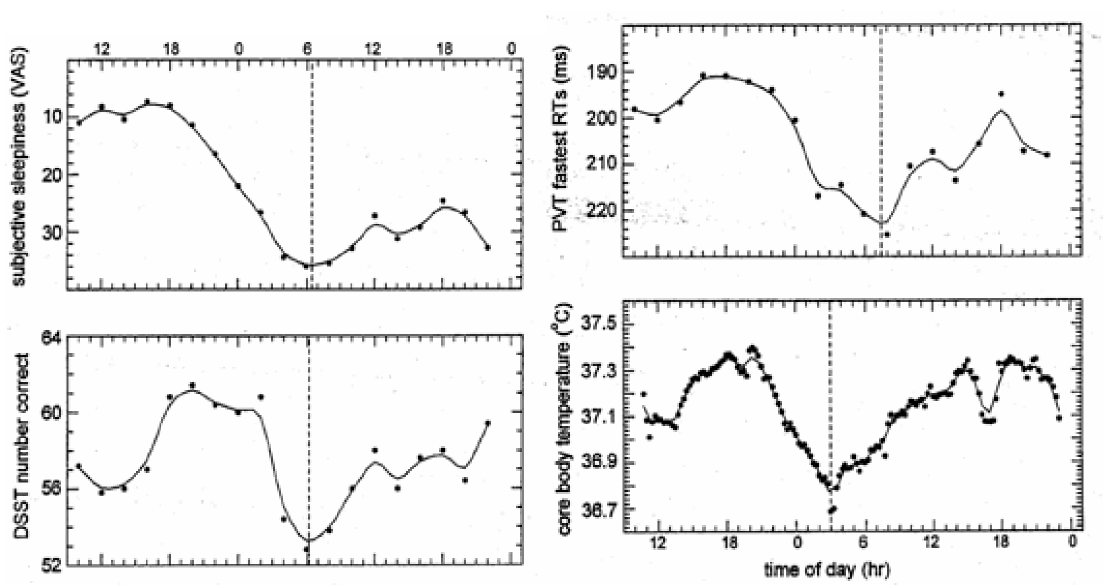

Figure 1. Temporal representation of circadian variation in a. subjective sleepiness; b. performance in a digit substitution task; c. reaction time task; d. body temperature. Van Dongen & Dinges, 2000

Interestingly, human alertness and fatigue levels generally rise and fall in conjunction with one's circadian rhythm. Core body temperature is one accurate method of determining a person's alertness level, and a graph of core body temperature over a 24-hour period closely corresponds to alertness level and circadian rhythm. In effect, core body temperature can be used as an accurate predictor of relative alertness over the course of a day and is termed a "circadian marker" (Hockey, 1983).

The other major factor regulating human fatigue and alertness is termed "sleep propensity". Sleep propensity is a measure of an individual's desire for sleep, based upon the length of time since their previous sleep period (Carrier & Monk, 2000). Sleep propensity is a part of the human homeostatic sleep drive, and if sleep is denied (for whatever reason), an individual will feel more fatigued with an increased desire for sleep throughout the course of the day. However, both the high and low arousal levels typically associated with the circadian rhythm still occur. Conversely, a longer sleep period will result in a lower level of sleep propensity (Carrier & Monk, 2000).

As can be seen, a human's overall drive for sleep is a relationship between the homeostatic sleep drive and the circadian rhythm, and there are both external and internal factors that can either mask or enhance the sleep drive. For example, a person who is very sleep-deprived may be highly alert in a combat situation. However, once that combat period is over with no subsequent stimulus, the individual's sleep drive may become even more pronounced due to the exertion and mental strain of the combat

episode. There are cases of counterattacks being successful because the defenders were asleep following such a situation (91st Infantry Division Unit History, 1945).

The timing of sleep can also be a factor in reducing or enhancing the sleep drive. If a person attempts to sleep during peak circadian alertness, the amount and quality of sleep obtained is generally reduced. Because the amount of sleep is less, there is an increase in the remaining sleep. On the other hand, if a person sleeps during circadian troughs, the amount and quality of sleep is generally greater, and subsequent sleep drive is reduced. Thus, in general, more sleep equals reduced sleep drive and resulting fatigue (Carrier and Monk, 2000).

2. Sleep Stages

Human sleep is divided into two categories, rapid eye movement (REM) and non-rapid eye movement (NREM). These two categories alternate throughout the course of sleep. NREM sleep is further sub-divided into four stages. NREM begins with sleep onset (Stage 1) and continues through Stage 4, each stage being "deeper" than the last. "Deep" is a term used to describe the relative intensity of a stimulus necessary to bring a person back to wakefulness. Rapid eye movement (REM) sleep can be easily determined by visual observation of the sleeper. REM is distinguished by rapid eye movement and can be directly observed as eye movement below the lids, and can be observed even among those individuals who do not fully close their eyes when asleep. If electroencephalographic recordings are being conducted, the REM stage is indicated by a burst of neural activity. One entire cycle of NREM and REM sleep lasts approximately 90 minutes, when another cycle begins anew.

This cycle continues throughout the sleep period (Carskadon and Dement, 2000).

As mentioned above, an EEG may be used to distinguish between the various sleep stages. Each stage in the sleep cycle is determined by a slightly different level or type of neural activity, also known as "brain waves". Figure 2 shows an EEG pattern for both NREM and REM sleep. Figure 3 shows an EEG pattern over time during sleep (Carskadon and Dement, 2000).

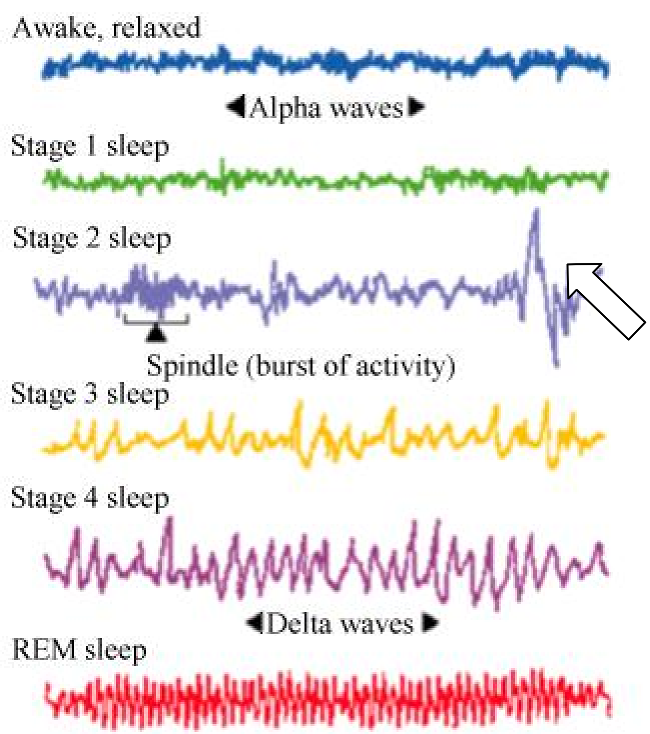

Figure 2. EEG of Human Brain Activity During Sleep. http://ist-socrates.berkeley.edu/~jmp/dreams.html August 26, 2005

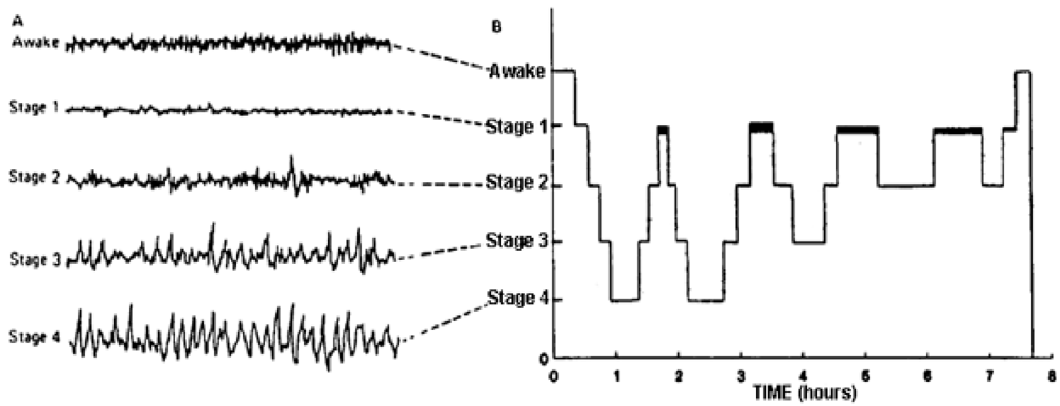

Figure 3. EEG of Human Sleep Cycle By Stage Over Time. http://www.holistic-online.com/Remedies/Sleep/sleep_stages-1-4NREM.htm August 26, 2005

Stage 1 sleep lasts for a very short period of time, usually less than 10 minutes. A person in Stage 1 sleep is easily awakened with physical contact, verbal stimuli, or a combination of both (Carskadon & Dement, 2000). Stage 1 sleep is generally conceptualized as a transition period to deeper stages of sleep, and is nonrecuperative. "Microsleep" episodes are short periods of Stage 1 sleep lasting from two to three seconds. Microsleep usually occurs among individuals who are bored or suffering from fatigue (Horne, 1988; Johnson, 1982).

An interesting facet of Stage 1 NREM is that a person will not recall the exact moment of falling asleep. In fact, a person will generally not recall the last few minutes prior to entering Stage 1 NREM (Wyatt, Bootzin, Anthony & Stevenson, 1992). The technical term for this circumstance is "retrograde amnesia". At least one study indicates that individuals experiencing excessive sleep drive (fatigue) may indeed experience memory problems related to this condition (Wyatt, Bootzin, Anthony & Stevenson, 1992).

Stage 2 sleep generally lasts longer than Stage 1 sleep (between 10 and 25 minutes) in most cases (Carskadon & Dement, 2000). It takes a somewhat stronger stimulus to awaken a person in Stage 2 sleep. As can be seen in Figure 3, the EEG appears somewhat different compared to Stage 1. Stage 2 eventually proceeds into Stage 3. The transition from Stage 2 to Stage 3 occurs when high-voltage slow-wave activity becomes the dominant output of the EEG. Note the similarity between the output at the end of the Stage 2 sleep pattern and the Stage 3 pattern in Figure 2.

It is the predominance of high-voltage "Slow-Wave Activity" (SWA) that distinguishes Stage 3 NREM sleep, the beginning of which is generally referred to as "Slow-Wave Sleep" (SWS) or sometimes "deep sleep". An individual requires an even greater stimulus to be awakened from Stage 3 NREM sleep (Carskadon & Dement, 2000).

Stage 4 NREM sleep is identified on an EEG when SWA occupies more than 50% of the recorded sleep activity. This is the deepest stage of sleep, and an individual requires considerable stimulation in order to be awakened. Stages 3 and 4 NREM occupy the majority of the sleep cycle in the early part of an eight-hour sleep period, up to 70 minutes of the 90 minute cycle (Carskadon & Dement, 2000).

Upon the conclusion of Stage 4 NREM sleep, a person moves rapidly into REM stage sleep. REM is generally associated with dreaming and with the paralysis of voluntary muscles (Carskadon & Dement, 2000). Voluntary muscle control is typically disconnected during the dream state, and this is likely a survival requirement so that individuals would not "thrash about" while dreaming, thereby making them vulnerable to nocturnal predators. As

can be seen in Figure 4, the timing of the various stages of sleep varies throughout the course of an adult’s 8-hour nightly sleep period. Deeper sleep stages dominate the earlier half of the 8-hour period, while REM becomes the dominant factor during the latter half of a night’s sleep.

However, a person’s sleep architecture does change with age. In general, the older the person, the less sleep they require. The various stages are divided into; infancy (up to age 2), childhood (age 2 to 12), adolescence (age 12 to 22), adult (age 22 to 60), and senior adult (over 60). The ages are averages, and there are certainly differences among individuals. Numerous publications document how sleep architecture changes from infancy to advanced age. Carskadon and Dement (2000) discusses these changes in detail.

C. SLEEP AND MEMORY CONSOLIDATION

Human cognitive functions are typically extremely complex in nature. These functions have proven difficult if not impossible, to objectively measure, and it is even difficult to assess cognitive functions subjectively. There even exists some controversy surrounding the effects of sleep (or the lack thereof) on learning.

Current sleep and cognitive research indicates that adequate sleep is a necessity when it comes to memory formation and consolidation. But how sleep aids in memory formation and consolidation is still a matter of debate. How and when memory consolidation occurs in the sleep cycle has not been definitively determined, e.g., REM, SWS, or a combination of both (Gais, Plihal, Wagner & Born, 2000; Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994).

Research has shown that during sleep, learned tasks are re-expressed and the corresponding neural pathways are both reinforced and improved (Wilson & McNaughton, 1994). Given a spatial behavioral task, the hippocampal activity of rats during subsequent SWS states closely corresponded to the same activity experienced during the spatial behavioral task itself. This activity increased from that exhibited during previously recorded sleep periods, and during each post-behavior sleep session, the hippocampal activity declined. The conclusion was that SWS helps to solidify the synaptic pathways necessary to recall and perform tasks by gradually transferring information from the hippocampus to the neocortex (Wilson & McNaughton, 1994).

In a similar experiment with human participants who were given a visual discrimination task, researchers found that the amount of learning was strongly dependent upon the type of sleep they were allowed. The subjects were divided into three groups: normal sleep, REM-deprived sleep, and SWS-deprived sleep. The normal and SWS-deprived groups showed improvement at a recently learned task. The REM-deprived groups showed less improvement in the same task. However, the SWS-deprived group showed a greater disruption in performing previously learned tasks when compared to the REM-deprived group. The conclusions of the study were that REM state is a key player in memory consolidation, as well as the development of "procedural memory". An additional conclusion is that REM state may have be related to long-term association memory (Karni et al, 1994).

Both of these studies highlight the importance of sleep as it pertains to learning, although they have

differing opinions of the roles played by REM and SWS when it comes to memory consolidation. There is recent research that supports a two-step model that states (in part) that both REM and SWS states are required for memory consolidation. One study, using human subjects showed that performance in a visual discrimination task did not improve when subjects were denied SW sleep. However, the group with a "standard" 8-hour sleep that included the usual SWS and REM stages exhibited an improvement 3-times greater than the sleep stage-deprived groups (Gais et al, 2000). As expected, the study concluded that sleep is essential to the human learning process.

In essence, sleep allows for the recovery and retention of tasks and experiences that occur during waking hours. Fenn et al, (2003) concluded that learning which occurs during the day is solidified during sleep. This occurs as neural pathways generated during the day's learning are exercised and refined during the sleep cycle. The study concluded that sleep is essential to the learning process as a whole.

D. ADOLESCENT SLEEP

The sleep patterns of human adolescents are distinctly different from adult and pre-pubescent sleep. Compared to adults or children, adolescents have a very different sleep drive, and the most readily apparent differences are a desire to stay up later at night and awaken later the next morning. In fact, adolescents can be further divided into two groups, based on their sleep behavior: early adolescents typically sleep longer than late adolescents, while late adolescents generally exhibit a later onset of

the sleep drive (Carskadon et al, 1997). For the parents of teenagers, then, there may be some slight consolation in realizing that having to work hard to get their children to bed at night and up in the morning has a biological basis.

But given no restrictions, an adolescent will typically go to bed later in the night and awake later the next morning. This change in sleeping habits is due to both biological and social forces acting upon the adolescent's circadian rhythm (Carskadon et al, 1997). Furthermore, environmental factors, such as higher academic requirements, a more active social life, and additional extracurricular activities can also impact an adolescent's sleep drive. Biological factors, particularly increased hormone production, also act to delay the timing of evening sleepiness (Carskadon, 2002; Carskadon et al, 1997).

1. Biological Influence on Adolescent Sleep Drive

Adolescents experience a marked decline in SWS, and this decline generates a weakened homeostatic sleep and awakening process (Carskadon, Acebo, & Seifer, 2001). The natural mechanism that regulates the sleep and wake cycles is weaker than in adults, and the adolescent nocturnal sleep period is not as efficient. This inefficiency is the result of less REM and SWS time during the entire nightly sleep cycle. Because of this inefficient sleep, adolescents appear to be chronically fatigued. As a result, adolescents often exhibit a tendency to sleep more on weekends in an effort to re-fill the sleep reservoir left at least partially, (if not substantially) empty by the week's activities (Carskadon, Acebo, & Seifer, 2001).

One of the main differences between adolescent and adult sleep drives is hormonal in nature. Melatonin is the

primary hormone regulating the sleep drive in humans, and this hormone is easily measured in salivary samples. In the absence of light, the pineal gland releases melatonin, which triggers the drive to fall asleep. The advent of electric lighting is one of the main factors contributing to the extended day in modern society, because light suppresses the release of melatonin from the pineal gland. Melatonin levels in adolescents are markedly different from those of adults over a 24-hour period. Compared to children, adolescent levels of salivary melatonin may decline by over 75%. But while melatonin levels decrease in adolescents, Luteinizing Hormone (LH) production increases. This increase initiates the production of various sex steroids, which in turn is responsible for sexual maturation (Waldhauser & Steger, 1986). Melatonin secretion is directly correlated with age, supporting the theory of "phase delay in" the circadian rhythm triggered by the onset of puberty (Carskadon, et al 1997).

2. Behavioral Consequences of Adolescent Sleep Patterns

In a two-year study of 6,632 high school students, the incidence of falling asleep in class, as well as overall daytime sleepiness increased with age (Giannotti & Cortesi, 2002). Earlier school start times (which ranged from 7:45 to 8:45 a.m.) had a direct impact on the student's overall behavior. Students attending school with an earlier start time had more incidents of falling asleep in class, complained of more daytime sleepiness, and experienced more irregular sleep schedules. In terms of academics, the students with earlier school start times also reported lower academic performance than the students who attended schools with later start times.

"Catch-up" sleep on weekends is a known measure of insufficient sleep during the week. About 19% of the students in the Italian high school study reported a difference in bedtime of three hours earlier on weekend nights compared to weeknights. This was clearly an attempt by those students to make up for the fatigue experienced due to sleep deprivation during the school week (Giannotti & Cortesi, 2002).

Another study of high school age adolescents had similar conclusions, particularly when it comes to academic performance (Wahlstrom, 2002). One school district in Minnesota moved junior high and high school start times to begin later in the morning during 1996-97, in an attempt to achieve higher overall academic performance in the student population. The results clearly showed that start times after 8:30 resulted in better academic performance for grades 8 through 12. Seventh grade performance peaked with a start time between 8:00 and 8:15. This study also showed that both genders appeared to benefit equally well from later start times (Wahlstrom, 2002).

E. COLLEGE AGE AND LATE ADOLESCENCE

College students are actually late adolescents for most of their matriculation, and most students do not begin to exhibit adult sleep patterns (with accompanying hormonal maturation) until between the ages of 22 to 25 (Carskadon, et al 1997). However, many of these students have a schedule that is at least as busy as that of an adult. This is particularly true for students working multiple jobs, and who may have children and/or a spouse, while carrying a full course load.

In a longitudinal study of college student sleep habits at Brown University, conducted by Carskadon, Wolfson, & Tzischinsky (1995), incoming freshmen exhibited a significant reduction of net nightly sleep between high school and college. Specifically, this sample experienced a median two-hour delay in nocturnal sleep onset (Carskadon, Wolfson, & Tzischinsky, 1995). Over the next two years, there was a gradual increase in reported net sleep time and a concomitant decrease in reported daytime sleepiness. This suggests that the students underwent behavioral or physiological alterations in order to cope with a significant change in their lifestyle (Acebo et al, 1991). In general, college students tend to go to bed later and wake up later than high school students and take more naps than their high school counterparts (Carskadon & Davis, 1989).

The academic performance of college students is also directly linked to their sleep habits. Trockel and others (2000) conducted a study whose goal was to determine the relative significance of a variety of variables on freshmen GPAs. They found that grades were inversely correlated with late-night weekday and weekend bedtimes, amount of weekend catch-up sleep hours, and the number of work hours per week. Getting more sleep through the work week, combined with working fewer hours in other jobs, and generally resulted in a higher GPA (Trockel et al, 2000).

F. SLEEP DEPRIVATION

1. Dangers

Sleep deprivation can have lethal consequences in all walks of life, but particularly so when it comes to making

important decisions and interacting with hazardous equipment or processes. Decision-making and machinery operation are particularly affected by sleep deprivation. Investigations following numerous fatal catastrophes, including the nuclear power plant failures at Three Mile Island (1979) and Chernobyl (1986) as well as the Space Shuttle ***Challenger*** accident in 1986 were caused in part by sleep deprivation (Mitler, Carskadon, Dement, Dinges, & Graeber, 1988).

Indeed, sleep deprivation is serious enough that U.S. Army units are required to have sleep plans that take sleep into account when conducting both tactical and administrative operations. In some Army units, leaders check subordinate leave travel plans to ensure that hotel reservations are made to ensure that soldiers do not drive too many hours without rest (2nd Armored Cavalry Regiment Safety SOP, 2001). Logistical transportation units are particularly vulnerable to sleep deprivation accidents, as they may spend hours on the road to make a delivery, only to circle back for another load and mission, and then head out again, repeating the cycle.

Army Aviation units take sleep deprivation so seriously that there are regulations that govern how much rest pilots must have during a 24-hour cycle (Army Regulation 95-1, 1997). This mandatory “crew rest” requirement often leads to some good-natured humor between ground-based officers (e.g., Infantry, Armor, etc.) who have no such requirement, and their aviation counterparts. However, these regulations only apply to the pilots, not the personnel who maintain the helicopters.

The challenges and effects of sleep deprivation are experienced in virtually every industry, government activity, and in daily life. In the aviation industry, Rosekind et al (1996) looked at pilot fatigue in trans-Pacific flights. The findings indicated that pilots in the later stages of a flight experienced a reduction in their reaction times of over 25 percent, and that pilots often fell asleep at or near the end of the flight. Most alarming, however, was that during the final 10 minutes of flight (approach and landing phases), five microsleep episodes were identified among the nine pilots in the study (Rosekind et al, 1996).

Lack of adequate sleep will both increase the homeostatic sleep need, and alter the circadian rhythm. Sleep deprivation will also increase the feeling of fatigue (often reported as “lack of energy”) and dampen morale. This may then lead to an increase in negative feelings in general. Often, sleepiness is an early warning indicator to a coming decrease in the individual’s performance. An extreme lack of sleep in a healthy individual will induce psychotic episodes or hallucinations in an individual who is not mentally ill (Horne, 1993). Indeed, Army Ranger School candidates regularly report transient hallucinatory episodes among their fellow candidates suffering extreme sleep deprivation. The story of a Ranger School candidate attempting to use a tree as a soda machine and becoming angry at the lack of a dispensed product is legendary, and perhaps may have a factual basis.

If lapses in attention due to fatigue occur during dangerous activities, the consequences to persons and property may be disastrous. Figure 4 displays the

distribution of fatigue-related vehicle accidents over a 24 hour time period. This distribution is correlated with documented circadian nadirs in alertness that occurs in early morning and early afternoon.

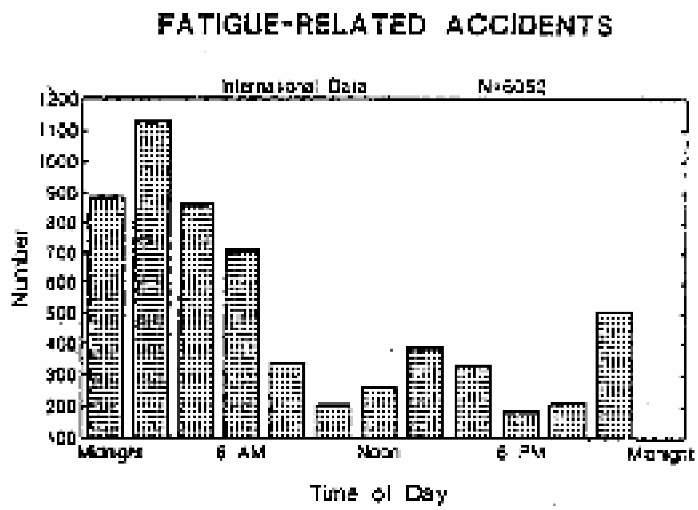

Figure 4. Temporal distribution of accidents as a function of daytime. Miller et al. 1988.

2. Human Performance Degradation

Researchers have made several attempts to model human performance under chronic sleep deprivation conditions. A classic study was conducted at the Walter Reid Army Institute of Research (WRAIR) in 2003. The study used the psychomotor vigilance test (PVT) and measured both sleep latency and subjective sleepiness, in order to quantify subject alertness and performance in a dose-response experiment (Belenky et al, 2003). When determining baseline performance, all groups received a mandatory eight hours of sleep for three consecutive nights. Participants were then randomly assigned to one of four treatment groups consisting of three, five, seven, or nine hours of sleep per night. Figure 5 shows the mean PVT speed and standard error throughout the course of the thirteen-day study.

During the seven days of sleep restriction, performance of both the five and seven hour groups decreased and then stabilized. However, the three hour group's performance continued to decrease, and showed no signs of an asymptote. As would be expected, there was no performance decrease for the nine hour group.

Once the sleep restrictions ended, all groups were allowed as much sleep as they desired over the remaining three days of the study. PVTs continued to be administered during the three sleep-recovery days. The performance of the three sleep-restricted groups improved, but did not return to baseline levels.

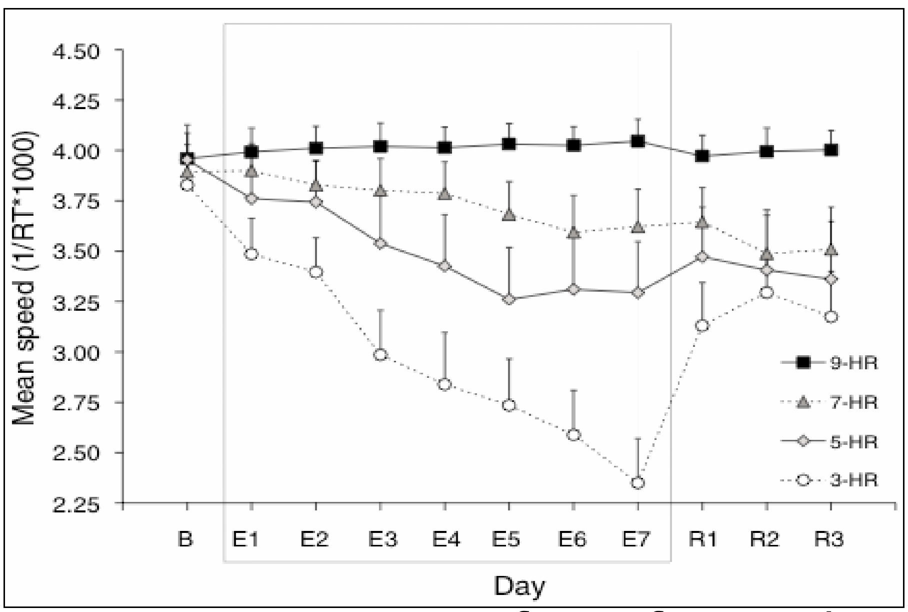

Figure 5. Dose response curve for performance in groups with 3, 5, 7, and 9 hours sleep. Belenky et al. 2003.

In a similar study conducted in 2003, three groups of 16 people each were place in three treatment conditions, consisting of either four, six, or eight hours of nightly sleep. Participants were monitored under laboratory conditions, and the treatments were administered for fourteen consecutive days. The sleep-deprived groups (four

and six hour treatments) resulted in cognitive performance deficits equivalent to individuals who were totally sleep-deprived over the course of two to three days. See Figure 6 for a visual representation of group performance changes. Measures of performance were the subjective sleepiness score, digit substitution task, and serial addition/subtraction task (Van Dongen, Maislin, Mullington, & Dinges, 2003).

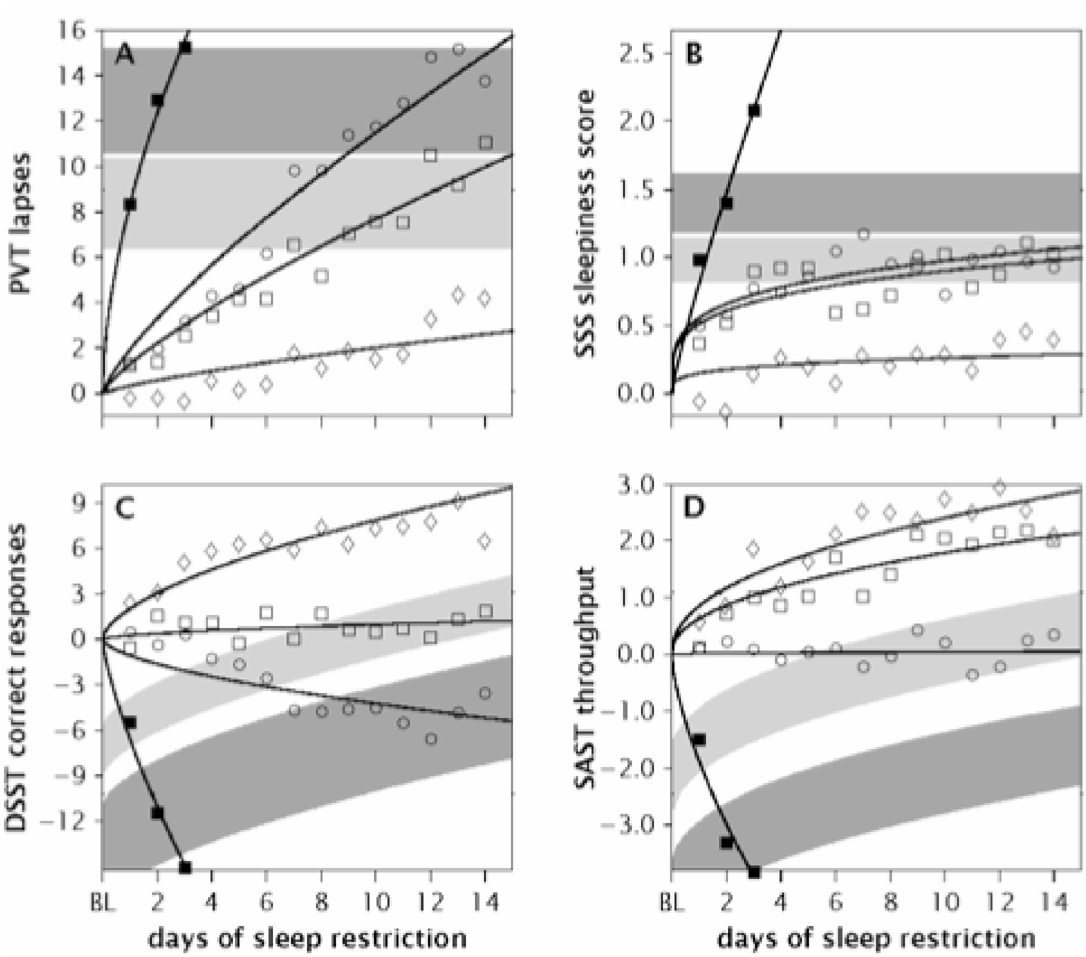

Figure 6. Results from dose-response study of 8(◊), 6(□), 4(O) hour chronic sleep conditions over 14 days. SSS sleepiness score = subjective sleepiness; DSST = digit substitution task; SAST = serial addition/subtraction task. These performance results are compared with total sleep deprivation(■) for 3 days. Van Dongen et al., 2003

The study also showed a modest positive correlation between average sleep duration for five days prior to the experiment, and the rate of increase in PVT lapses over the course of the experiment. This suggests that those individuals who lived "normally" sleep-deprived lives ***may*** have been less affected by the fourteen sleep-restricted days of the study. Another possibility is that these individuals may be among those who require less than eight hours of nightly sleep to achieve optimal daily cognitive performance. The study results indicate that individuals may not be able to accurately assess their own sleepiness levels under chronic sleep deprivation conditions (Van Dongen, Maislin, Mullington, and Dinges, 2003).

The results of both studies suggest that human performance degrades, and then stabilizes at some point under all but the most severe sleep-deprivation conditions. Another conclusion is that the effects of chronic sleep deprivation are not limited to certain parts of the day. Finally, the fact that neither of the control groups exhibited performance degradation is evidence that the other treatment group's performance was not due to boredom, monotony, or non-compliance with the test measures, (which presumably would have appeared in the control groups as well).

Physical performance degradation resulting from sleep restriction is somewhat more difficult to quantify. It appears that physical work capacity is unchanged by high levels of sleep deprivation. In other words, an individual can still perform physical tasks, such as lifting an object, at about the same performance level regardless of how sleep deprived they are. However, tasks are performed

more slowly as the desire to rest (sleep) increases. Overall endurance is reduced by 20% under sleep deprivation conditions (Naitoh, Kelly, and Englund, 1989).

One measurable physiological change in sleep-deprived humans involves insulin. Under chronic sleep deprivation conditions, humans develop an apparent tolerance to insulin, and this results in glucose levels in the blood increasing, leading to physiological changes similar to those found in diabetes (Naitoh, Kelly, and Englund, 1989).

Not surprisingly, sleep deprivation has a negative effect on the function of the prefrontal cortex (PFC) of the brain. The PFC regulates wakefulness and arousal, and also is involved in other cognitive functions, including planning and discrimination tasks. PFC deficits can lead to feelings of apathy, indifference, and reduced motor activity. During the sleep cycle, the PFC is least active during the SWS portion. It is more difficult for humans to "mask" PFC-related decrements involving motivation or incentive than with non-PFC dominant tasks (e.g., vigilance) (Horne, 1993).

3. Sleep Architecture Changes

Human sleep architecture changes under sleep deprivation conditions. The changes that occur are primarily affected by the duration of prior wakefulness, and there is an increase in Stage 3 and 4 SWS levels (Borbely, Baumann, Brandeis, Strauch, & Lehmann, 1981). Figure 6 presents a graphical representation of these results. As can be seen, a latent onset of REM sleep accompanies the increase in SWS. One study of adolescents resulted in an average of 155 minutes REM latency, whereas the control group averaged 103 minutes (Carskadon, Acebo, &

Seifer, 2001). In essence, adolescents under sleep deprivation conditions will take longer to reach the REM stage, due to spending additional time in Stages 3 and 4 NREM sleep.

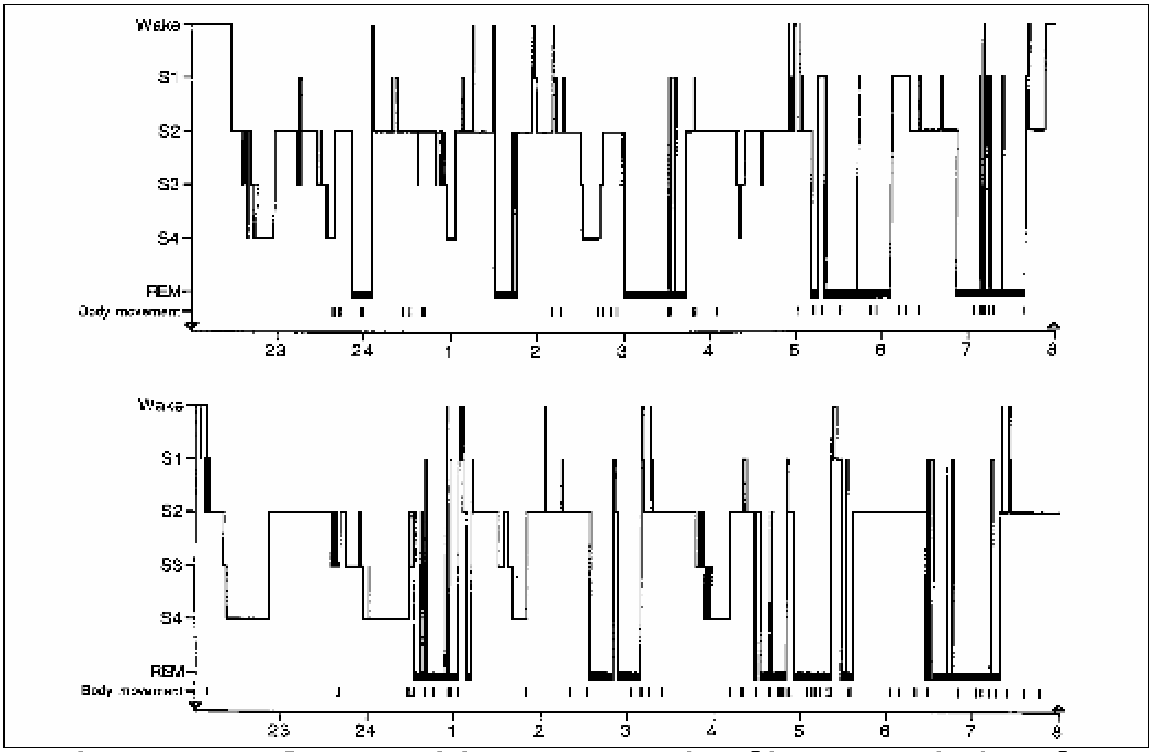

Figure 7. Sleep Architecture. The first graph is of a normal night of sleep.The second is from a night of recovery sleep. Notice a delay in the first REM cycle and the density of SWS in the recovery night. Carskadon and Dement, 2000.

4. Masking the Effects of Sleep Deprivation

It is a relatively common misconception that, given enough motivation, interest, or stimulation in an activity, the effects of sleep deprivation may be overcome. However, for highly complex cognitive tasks, sleep deprivation can lead to an increase in visual and auditory distractions. For tasks of less than ten minutes in duration, however, if an individual has sufficient interest or motivation, it is possible to overcome the physical and cognitive decrements

associated with sleep deprivation. This effect is called "masking". However, if the task requires the involvement of the PFC, performance decrements associated with sleep deprivation are typically identified considerably sooner, as the decrements occur more quickly and with greater intensity (Harrison & Horne, 2000).

G. COUNTERMEASURES OF FATIGUE

There are three basic categories of fatigue countermeasures: naps, stimulants, and hormones. Naps and hormones such as melatonin may be used in conjunction with each other because melatonin increases the sleep drive, rather than reducing it. Stimulants, on the other hand, do not assist in fatigue reduction, but merely mask its effects using pharmaceuticals. Interestingly, there are few research efforts underway that are investigating whether the long term use of these countermeasures has an effect on human health and performance. What follows is a discussion of some of the means of increasing alertness while combating fatigue. Furthermore, it is important to note that the effects of habituation to these countermeasures have not been fully explored. Also, the effects of nicotine (a stimulant) are not discussed here, because of the known adverse health effects of the typical delivery systems for this substance (e.g., tobacco products). Of these countermeasures, only caffeine is readily available to New Cadets during CBT, due to the daily activity schedule.

1. Naps

Naps may be used as a means to increase human performance when individuals are sleep deprived. However,

the length and timing of a nap during the day is important if the desire is to maximize the nap's ability to re-fill the sleep reservoir. There is continued debate as to the efficacy of naps, but most of the evidence indicates that, while a nap may decrease performance in the short term, over the long term, naps are beneficial and are far better than doing nothing to overcome sleep deprivation's negative performance effects.

Sleep inertia is the term for the effects of confusion, sluggishness, disorientation, and lack of motivation. Sleep inertia significantly degrades performance on cognitive tasks, and lasts for a variable period of time (Dinges & Kribbs, 1991).

Sleep inertia may be a short term challenge posed by napping. In a study by the Naval Health Research Center (NHRC), sleep inertia was reported to worsen in direct proportion to the cumulative sleep debt. In addition, the circadian timing of the nap did not affect the amount or time duration of sleep inertia, or the long-term benefits of the nap. The level and duration of sleep inertia is far more dependent upon which stage of sleep the individual is experiencing when woken than the circadian timing or duration of the nap. The most severe sleep inertia occurs when the individual is awakened from SWS (Naitoh, Kelly, & Babkoff, 1991).

Another study supports the results of NHRC's work in the area of sleep inertia. Four treatment groups were given 15, 30, 60, and 120 minute naps respectively. Differences in performance after these naps did not appear within two hours of any nap (Lumley, Roehers, Zorick, & Roth, 1986). This two hour period corresponds closely with

the typical period of sleep inertia after a nap (Naitoh, 1981). Once the sleep inertia dissipated, however, the arousal effects of the naps were quantifiable. SWS duration peaked during the 60 minute nap, and the 120 minute nap group displayed more REM and stage 2 sleep elements (Lumley, Roehers, Zorick, & Roth, 1986).

Naps had an arousing effect for sleep-deprived individuals. The effects were positively correlated with the duration of the nap itself. The highest level of alertness during the 8 hours of post-sleep inertia testing was achieved in the 60 minute treatment group. However, the alertness in the individuals never reached baseline (non-sleep deprived) levels. The 120 minute treatment group showed no appreciable increase in alertness over the 60 minute group. There was only a slight positive correlation in alertness level with the increased amount of SWS in the 120 minute treatment group.

A different study showed that naps increased alertness levels after the two hour sleep inertia period. This was particularly true for reaction time (RT) tasks. Interestingly, most of the subjects were not aware of their increased performance. A different conclusion from other studies was that the placement of the nap was not important, but getting any sort of nap prior to missing a night of severe or complete sleep loss was beneficial to performance (Dinges et al, 1987).

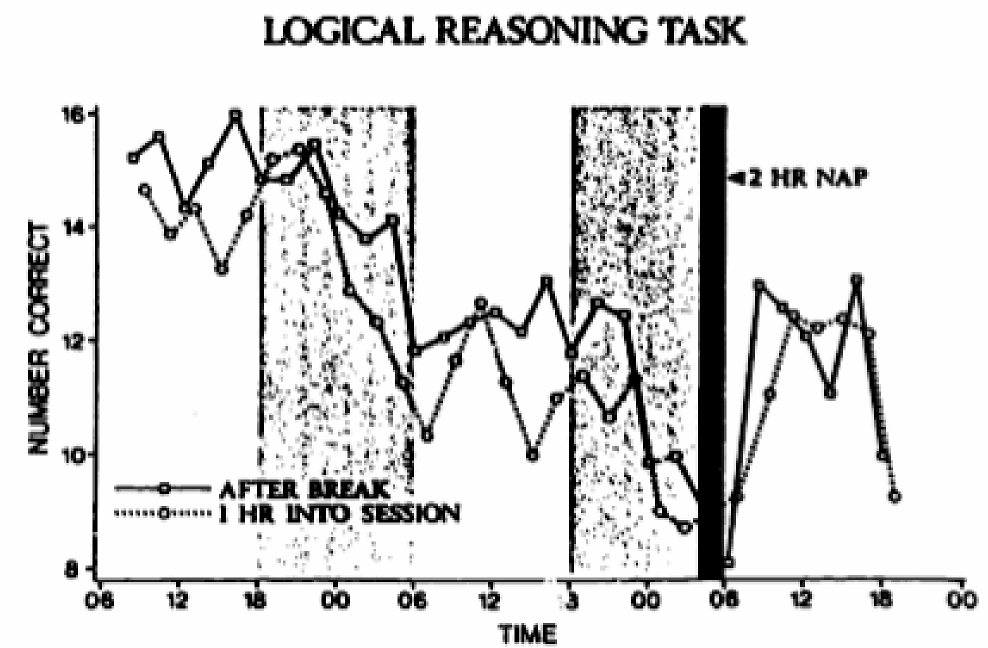

Figure 8. Performance throughout the daytime at a short (2 minute) logical reasoning task. Note the recuperative effects of a 2 hour nap at 0400. From Naitoh & Angus, 1987.

A study involving nurses in Japan concluded that ensuring that nurses took a two hour nap during a sixteen hour night shift significantly decreased self-reported fatigue following a variable duration of sleep inertia (Takahashi, Arito, and Fukuda, 1999). A study of industrial workers in France had a similar result; a short nap during the night shift had a positive impact on increasing the level of vigilance during the early morning hours (Bonnefond, Muzet, Winter-Dill, Bailloeuil, Bitouze, Bonneau, 2001).

2. Caffeine

Caffeine is a naturally-occurring alkaloid stimulant that effects on both the body and the brain. It increases the metabolism by escalating the rate of fatty acid manufacture (Gillin & Drummond, 2000). Once ingested, caffeine has a half-life in the human body of from three to

seven hours, depending upon the individual. Caffeine's stimulant effect improves memory and increases energy levels in both mental and physical tasks (Gillin & Drummond, 2000).

In a study to measure the effect of the mid-afternoon circadian nadir on performance, researchers in England utilized a driving simulator. When the subjects ingested caffeine in the form of coffee, the resulting number of microsleeps and swerves due to inattention decreased in comparison to the control group (Reyner and Horne, 1995). Caffeine combined with a 30 minute nap reduced microsleeps and swerved by nearly a factor of four (Dement, 1999). Since humans tend to build up a tolerance to caffeine, it should be used sparingly in order to maximize its effects a low dose levels. Caffeine is also slightly addictive in nature, and humans experience some withdrawal symptoms. The most common of these symptoms is a headache. This is why many headache relief medicines contain caffeine as a relief for what is in reality caffeine withdrawal, rather than a true headache.

A study of Navy SEALs (Sea-Air-Land) candidates also found that caffeine was a performance enhancer. The study population (68 SEAL candidates) were randomly assigned to one of four treatment groups; 100, 200, 300mg of caffeine or a placebo. They then underwent a 72 hour sleep deprivation training regimen (this is typical of the training program in general). Following the treatment, the candidates took a cognitive performance test which measured elements of visual vigilance, reaction time, and memory tasks. State of mood, marksmanship, and caffeine blood levels were also measured. The 200 and 300mg treatment groups showed increased performance over the other groups in the areas of visual

vigilance, reaction time, self-reported fatigue and sleepiness, and overall alertness. Marksmanship performance did not improve based on caffeine dose. Caffeine's effects seemed to be most pronounced approximately one hour after dose administration (Lieberman et al, 2002).

3. Melatonin

As discussed previously, melatonin is a naturally produced hormone in humans, manufactured by the pineal gland. Melatonin release is the major hormonal cue in activating the human sleep drive. However, the pineal gland typically shuts down melatonin production when light hits the retina (Horne, 1998).

Melatonin is often used to treat insomnia. It is also used to reset the circadian clock by travelers attempting to avoid jet lag. Melatonin is an over the counter substance, but has not yet been approved by the FDA for use as a sleep aid. There is as yet no evidence that the use of melatonin is harmful, though frequent use by adolescents may delay the onset of puberty (Kitay, 1954).

H. MEASURING SLEEP

Until recently, the methods used to measure sleep were intrusive and challenging for both the participant and the researcher. Polysomnography (PSG) is the current standard for measuring sleep in the laboratory. This method generally uses an electroencephalogram (EEG) for measuring sleep, and this device requires a number of leads to be placed on various areas of the subject's head, sometimes leading to uncomfortable sleep postures for the participant. PSG is a highly accurate (some would say

definitive) method for quantifying sleep. It is still considered the best method available to determine the identification, timing, and duration of the various sleep stages. Field studies using PSG are difficult, if not impossible to execute, because of power requirements, limited portability, and sensitivity to damage (Bloch, 1997).

Actigraphy is a relatively recent development in the conduct of sleep research. It is a non-invasive technique that allows the researcher to monitor human activity, to include sleep and waking periods. An actigraph is a wrist-worn accelerometer, a device that measures and records any type of motion or movement, and is more commonly called a Wrist Activity Monitor (WAM). A WAM has the ability to collect data over weeks or even months, depending upon the WAM model and battery life, and activity may be monitored in as little as 1-minute intervals (Acebo et al, 1999). These devices are extremely shock-resistant, water-resistant, rugged, and require little or no monitoring of each participant by the researcher. They are typically used to conduct field research, and can be used in virtually any environment. However, actigraph models differ in their sensitivity to movement. And although relatively rare, in some cases individual actigraphs of the same model will also differ slightly when measuring movement.

WAMs do not measure sleep directly. They merely record data to indicate whether or not movement has occurred, and to what extent. Following data collection, the data are downloaded to a computer via a serial cable, cleaned, and processed using specialized software. The

scoring programs use existing algorithms to separate the data into periods indicating both motion (awake) and non-motion (sleep) segments.

While convenient and easy to use, there are some challenges when using WAMs to measure activity or the lack thereof. Insomniacs and restless sleepers will generate sufficient activity during sleep that this motion will appear to be a wake period when the data is analyzed. Conversely, if a subject is very still while watching television for a period of time, the WAM will not record movement data, and this will typically be scored as sleep by the software. Removing the WAM, such as while bathing or swimming, may also result in that segment being scored as sleep by the software (Sadeh, Avi, & Acebo, 2002). The most common method for determining when the user has removed the WAM is to use sleep logs kept by each participant, along with follow-up interviews by the researcher to attempt to clear up any discrepancies.

Research indicates that at least five days of data recording should be utilized to allow for accurate sleep measurement (Acebo et al, 1999). This allows for the aggregation of the data and is the best way to obtain the average sleep by participants. Obviously, the more continuous a data sample is, the more accurate the estimation of individual sleep-wake periods will be (Sadeh, Avi, & Acebo, 2002).

I. HUMAN FATIGUE AND PERFORMANCE MODELS

Scientists have developed numerous models in an attempt to predict human performance as it pertains to sleep and circadian rhythm. The Department of Defense

(DOD) has sponsored the development of a homeostatic fatigue model that can be used to predict human performance as a function of sleep deprivation-induced fatigue. Such a model would allow the ability to plan and execute countermeasures and sleep-management strategies, and to predict the effectiveness of individuals based on their sleep patterns (Eddy & Hursh, 2001).

The result of this effort is the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model, developed by Science Applications International Corporation (SAIC) for the Air Force Research Laboratory. The SAFTE model is merely the latest of a series of efforts to quantify human performance, and predict both cognitive capability and task effectiveness, based on sleep (Eddy & Hursh, 2001).

The primary concept of the SAFTE model is that sleep is a type of reservoir, emptied by waking activity, and filled by sleep, which includes naps. The relative level of the reservoir is the homeostatic component of the model, and the rate at which sleep refills the reservoir is in direct proportion to the total sleep deficit (i.e., how "empty" the reservoir is). This model demonstrates a complete rebound in performance when recovery sleep occurs after chronic sleep deprivation. Thus, an hour of sleep for a rested individual will create only a marginal performance increase compared to an individual who is severely sleep-deprived (Eddy & Hursh, 2001).

The SAFTE model combines the sleep reservoir concept with the concepts of circadian rhythm and sleep inertia to predict performance. There are some limitations to the model, however. The SAFTE model's algorithms do not take environmental factors, stressors, or medications into

account when predicting performance. For example, the model does not include stimulant (such as caffeine) or depressant (such as alcohol) use, individual motivation levels, or if the individual is in a combat environment. Another limitation of the model is the assumption that eight hours of sleep is sufficient for everyone to achieve maximum performance. Essentially, the model uses the "average human" in making predictive calculations, but this is likely sufficient when used with larger groups in a predictive capacity (Eddy & Hursh, 2001).

III. METHOD

The objective of this thesis is to identify the sleep patterns of New Cadets of the West Point Class of 2007 during Cadet Basic Training (CBT). A secondary objective is to identify the sleep patterns of the Cadet training cadre during CBT. This effort is part of a four-year longitudinal study beginning with the Class of 2007 report date in June 2003 to their graduation in 2007.

During CBT, New Cadet participants were selected by a sampling technique that stratified by gender, unit, and recruited athlete status. The individuals selected wore WAMs throughout CBT and Reorganization Week to collect data on the amount of sleep they were getting during this 7-week period.

This research involves the collection and analysis of WAM data, combined with knowledge of the CBT training schedule in order to establish a measure of performance for each of the study population of New Cadets.

A. PARTICIPANTS

The participants for this study are the 1314 cadets of the Class of 2007 at the United States Military Academy, West Point, New York. On Reporting Day, they ranged in age from 17 to 23 years old, with the mean age of the group being is 18.7 years (with a standard deviation of approximately 11 months). As all potential entrants undergo a rigorous medical screening examination prior to acceptance, it was assumed that this group would be considered healthy. Additional admission requirements include minimum standards on SAT or ACT examinations, and

demonstrated potential for leadership aptitude. Due to the admission and selection process, any class of USMA cadet cannot be considered a random sample of the entire college-age population, although it is clearly a highly selective and extremely likely-to-succeed sub-set of this population.

The profile for the Class of 2007, as compiled by USMA's Admissions Office follows:

Volume of Applicants

	Men	Women
Applicant Files Started......	10,009	2,679
Nominated.....................	3,743	696
Qualified..................... (academically, and in physical aptitude)	2,101	376
Admitted......................	1,120	194

Rank in High School Class

First Fifth......	76%
Second Fifth.....	18%
Third Fifth......	5%
Fourth Fifth.....	1%
Bottom Fifth.....	0%

American College Testing (ACT) Assessment Program Scores*

Range	Eng	Math	Sci Reas	Read
31-36	25%	28%	18%	45%
26-30	54%	56%	52%	42%
21-25	21%	16%	29%	12%
16-20	0%	0%	1%	1%
11-15	0%	0%	0%	0%
Mean	28	29	28	30

College Board Scholastic Assessment Test (SAT) Scores*

Range	Verbal	Math
700-800	18%	25%
600-699	51%	57%
500-599	29%	18%
400-499	2%	0%
300-399	0%	0%
Mean	630	652

*Includes only scores used as a basis for admission.

Academic Honors

Class Valedictorians..............................	100
Class Salutatorians...............................	59
National Merit Scholarship Recognition............	192
National Honor Society............................	824

Activities

Boys/Girls State Delegate......................	232
Class President or Student Body President.......	234

School Publication Staff
School Paper Editor, Co-Editor of Staff....... 161
Yearbook Editor or Co-Editor................. 117
Debating.. 165
Dramatics....................................... 171
Scouting Participants........................... 550
Eagle Scout (men) or Gold Award (women)....... 194
Varsity Athletics
Letter Winner................................. 1,197
Team Captain.................................. 792

Geographical Distribution

The Class of 2007, numbering 1,314 new cadets, includes 1,302 United States citizens and 12 international cadets. Cadets were appointed by Congress from every state in the United States, as well as others appointed from military service sources. The international cadets are from the countries of Benin, South Korea, Ecuador, Kazahkstan, Costa Rica, Egypt, Phillipines, Kuwait, Kyrgyzstan (2), Tunisia and Taiwan. These cadets will return to their country as officers in their armed forces.

For this study, a sample of 80 New Cadets was stratified by gender, unit, and athletic recruit status. Ten New Cadets from each of the eight companies were selected for WAM data collection. Half of the participants were recruited intercollegiate athletes, and half were not. Females were over-sampled to allow for statistical power. In the study population, thirty percent of the participants were female, as compared to the 14.8% female in the class as a whole.

It is important to understand the nature of the daily routine for both the New Cadets during CBT. The schedule for the New Cadet's training is rigid, predictable, and known in advance for all of the participants. New Cadets have training throughout the entire week, and there is very little "free time" available including Sundays. The cadre exists to provide leadership, training, and indoctrination to the New Cadets as they transition from civilians to soldiers and burgeoning leaders. Squad leaders do the

majority of this work, followed by the platoon leaders and platoon sergeants. The Regimental leaders spend their time in overall supervision of training.

The atmosphere for CBT is like that of initial entry training (the more common term is "basic training") for the Army. New Cadets complete all the requirements of initial entry training, but they also have to learn West Point-specific requirements, including their expected behavior as 4th Class Cadets and rote memorization of West Point traditions such as the Alma Mater. Fourth Class Cadets would be the equivalent of freshmen at civilian universities, but at USMA they are referred to as "plebes". A typical training day schedule would be:

TIME	A	B	C	D	E	F	G	H
0500	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG
0530								
0600	MSE (AS2)	Guerrilla drills/Relays (AS2)	MSE	MSE	Guerrilla drills/Relays	Guerrilla drills/Relays	CQC 1 See Note 4	FT March to LN
0630								
0700	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	MNT / HYG	Box Bfast
0730	Uniform: BDUS (W/G G & H)			Breakfast				LN (J3)
0800	SBI Test	CDR'S TIME			WPNS Issue	Foot MVMT		
0830			DFL III	IP 8	Truck MVMT	1ST AID COMMITTEE	CQC 2 0830-1030	
0900			*OR* Peak Briefing WH5326					
0930	LOC: WH5300							
1000	CDR'S TIME	Customs see Note 5			INDIVIDUAL TACTICS & TECHNIQUES			
1030				LOC: Bldg 687			Truck MVMT	
1100						LOC: Behind Soldiers Statue	WARRIOR COMPETITION SITE	
1130		Etiquette TRN		See Note 3				MRE
1200	Customs see Note 5	LOC: TH144	Lunch - 1145					
1230			IP 8		LOC: J3			
1300	Lunch	Lunch		Lunch	MRE	MRE		
1330		SBI Test		DFL III				

TIME	A	B	C	D	E	F	G	H
1400				*OR* Peak Briefing WH5326	Foot March	1ST AID COMMITTEE	MRE	
1430	Etiquette TRN LOC: TH144						Foot MVMT	
1500		LOC: WH5300	LOC: Bldg 687 See Note 3					TRUCK MVMT
1530					RECOVERY			
1600	MASS ATH	MASS ATH	MASS ATH	MASS ATH			CQC WPNS	MASS ATH
1630					WPNS T/I	Foot MVMT		
1700								
1730								
1800	DINNER							
1830								
1900	**10-H NON-TOLE** NOTE	**10-H NON-TOLE** NOTE	**Uniform Inspections** LOC: CO Area		**10-H NON-TOLE** NOTE	**10-H NON-TOLE** NOTE		
1930								
2000							**10-H NON-TOLE** NOTE	
2030								
2100								
2130								
2200	NEW CADET TAPS							
2230								
2300								

NOTE 2: 0530 REVEILLE, 1800 RETREAT

NOTE 3: IP8: All Platoons March to Bldg 687 in 15 minute intervals; March back by Platoon

NOTE 4: CQC 1: Form up for REVEILLE at the CQC site

NOTE 5: customs Locations

Table 1. Example Training Schedule for CBT

B. PROCEDURES

The 1289 entering members of the Class of 2007 reported for duty at West Point at the end of June, 2003. CBT started immediately upon entering the barracks area. All members of the entering class took a Pre-CBT survey. This survey collected demographic data and information about their sleep patterns for the 30 days prior to reporting to USMA. Additional information was collected on tobacco use, caffeine consumption, and any medications taken during this 30 day period. Lastly, all individuals answered questions adapted from the Pittsburgh Sleep

Quality Index (PSQI), in an attempt to collect individual sleep data for the period prior to their reporting to West Point. The results of this effort are part of a separate study, and will not be discussed in this thesis.

The 80 New Cadets in the study group were issued WAMs, along with instructions for their use and care on 1 July 2004, and data collection began on that date. Unfortunately, one WAM malfunctioned early in the study, reducing the sample from 80 to 79. The original intent was for the New Cadets to wear the WAMs throughout Cadet Basic Training and Reorganization Week, but the actual data collection time ranged from 16 to 51 days. The data collection period for New Cadets ended on 15 August, when the WAMs were turned in.

Activity and sleep logs were not utilized during the data collection period because the inflexible New Cadet schedule precluded naps, while both bedtime and wake-up time are highly regulated.

At the end of the data collection period, the data were downloaded from each actigraph. Following data cleaning and consolidation, the data were analyzed using commercially available sleep and statistical analysis software.

C. APPARATUS

1. Actigraphy

Each subject was issued an ActiWatch WAM, manufactured by the Mini Mitter Company, of Bend, Oregon. The ActiWatch contains an accelerometer that records motor activity. Prior to beginning data collection, each WAM was calibrated, which consists of loading the correct time and

date into the Actiwatch, and this is followed by initialization. Initialization consisted of programming the WAMs to group the data collection periods at 1-minute time intervals, and this interval is known as the epoch length.

At the conclusion of each data collection period, the ActiWatches were collected from the participants. The data from each ActiWatch was then downloaded for initial analysis by Mini Mitter's Actiware program. This proprietary software performs data analysis and calculates such items as sleep duration, efficiency, and latency.

This software uses raw ActiWatch data to generate quantitative and visual representations of a subject's activity level, and this output is known as an Actigram. Activity is represented in the Actigram window by vertical bars. Generally speaking, the height of the vertical bar, indicates the level of movement that was sensed by the ActiWatch. Information is generated for each day on sleep start and end times, total time in bed, assumed sleep time, and sleep efficiency. See Figure 9 for an example day's output.

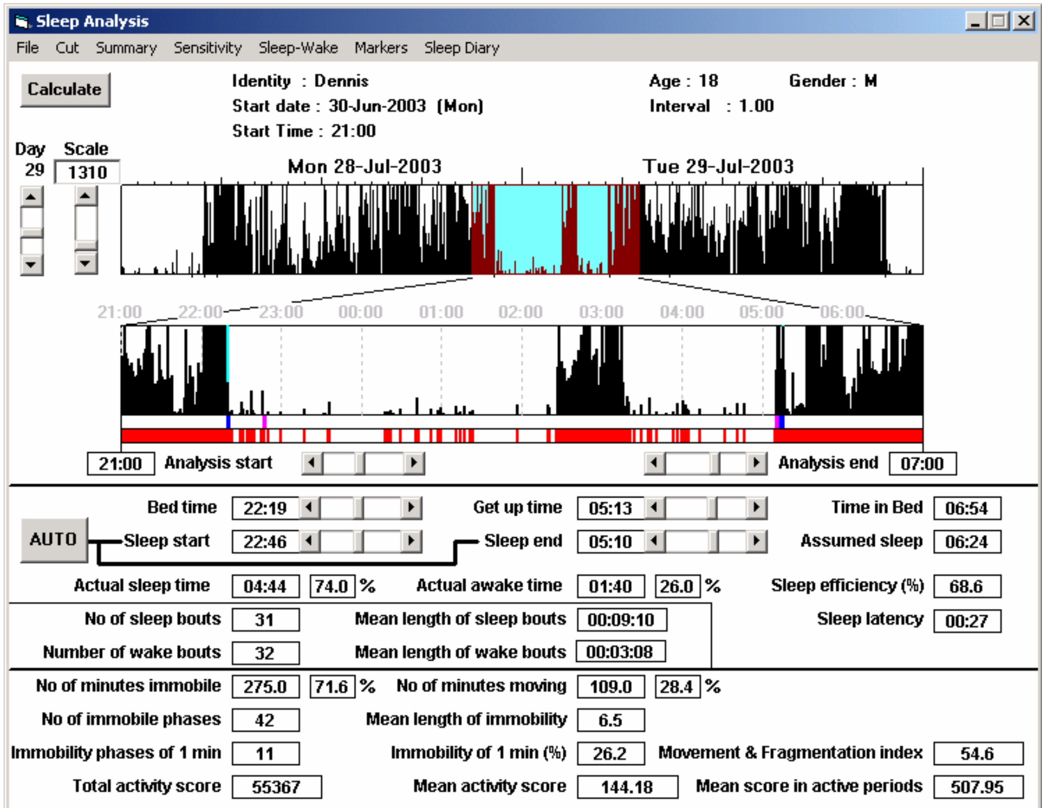

Figure 9. Example Actigram Output

The Actiware software used for the study calculates nap and nightly sleep separately, but because the CBT schedule prevents New Cadets from taking naps, only overnight sleep analysis was performed.

2. Data Analysis

Upon completion of the initial analysis using the Actiware program, the daily sleep duration for each subject was analyzed using Microsoft Excel®. Average and median sleep duration for each subject was calculated based on the total number of days of participation by each subject. The mean nightly sleep for each subject was then recorded for population analysis. In addition, the New Cadets with the most, median, and least amount of mean nightly sleep were identified.

Data from these three New Cadets were then input into another software program, called the Fatigue Avoidance Scheduling Tool (FAST) (Refer to Section II). FAST output is a graph of predicted task performance, based on sleep and naps obtained by the participant. The FAST output also includes a blood alcohol content equivalence on the right side of the output. This scale is designed to equate the level of individual sleep deprivation with the equivalent impaired performance typically experienced by a person following alcohol ingestion. See Figure 10 for an example.

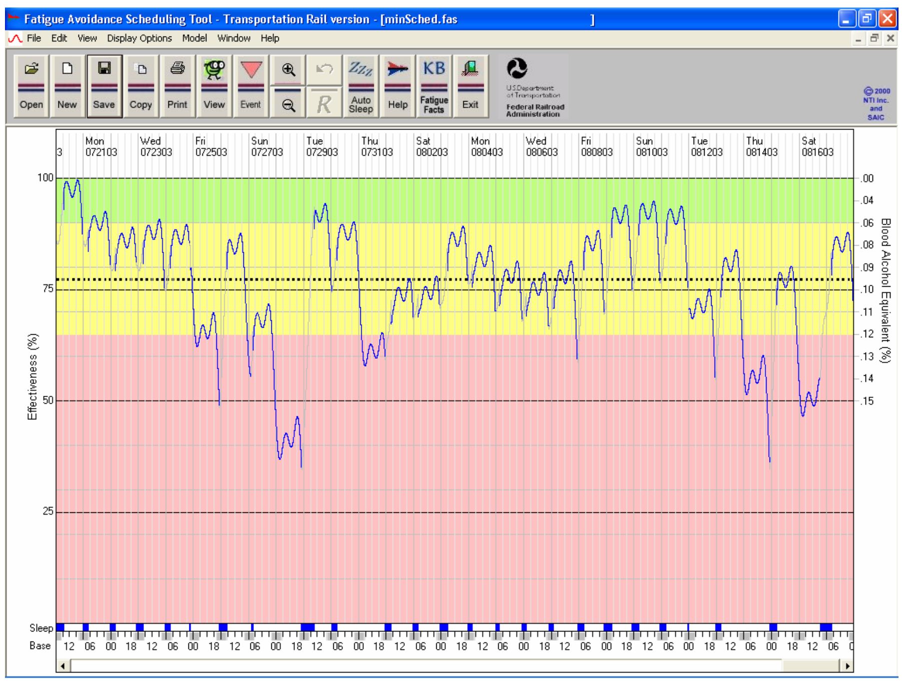

Figure 10. Example FAST Output

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IV. RESULTS

A. NEW CADET STATISTICAL ANALYSIS

The study sample contained 79 New Cadets. Demographic data:

56 Males (70.9%)
23 Females (29.1%)

55 Caucasians (69.6%)
9 African-American (11.4%)
7 Asian-American (8.9%)
4 Hispanic-American (5.1%)
3 Native-American (3.8%)
1 Other (1.3%)

38 Recruited Athletes (48.1%)

Average age: 18.2 years
Maximum age: 22 years
Minimum age: 17 years

In order to determine statistical significance when comparing categorical groups, the Tukey-Kramer "Honestly Significant Difference" (HSD) Test with $\alpha=0.05$ was utilized. For continuous data (Age only in this case), a bivariate fit was utilized, and a bivariate normal ellipse with $p=0.95$ was placed on the plot, along with a linear regression fit line.

1. New Cadet Total Population Sleep Analysis

The mean nightly sleep for each participant was used for the statistical analysis. The descriptive statistics for the New Cadet study sample sleep are as follows. Note that time values are in Hours:Minutes:Seconds format.

Mean	5:39:56
Standard Error	0:02:48
Median	5:44:35
Standard Deviation	0:24:52
Sample Variance	0:00:26
Kurtosis	1.23563235
Skewness	-0.6782952
Range	2:12:01
Minimum	4:25:57
Maximum	6:37:57
Sum	18.648872
Count	79
Confidence Level(95.0%)	0:05:34

Table 2. New Cadet Descriptive Statistics

The results show that the study sample (N=79) received approximately 5 hours, 40 minutes of sleep nightly, with a standard deviation from the mean of approximately 25 minutes.

A histogram of the study sample, using 15-minute bins from four hours to seven hours of sleep per night shows the following distribution:

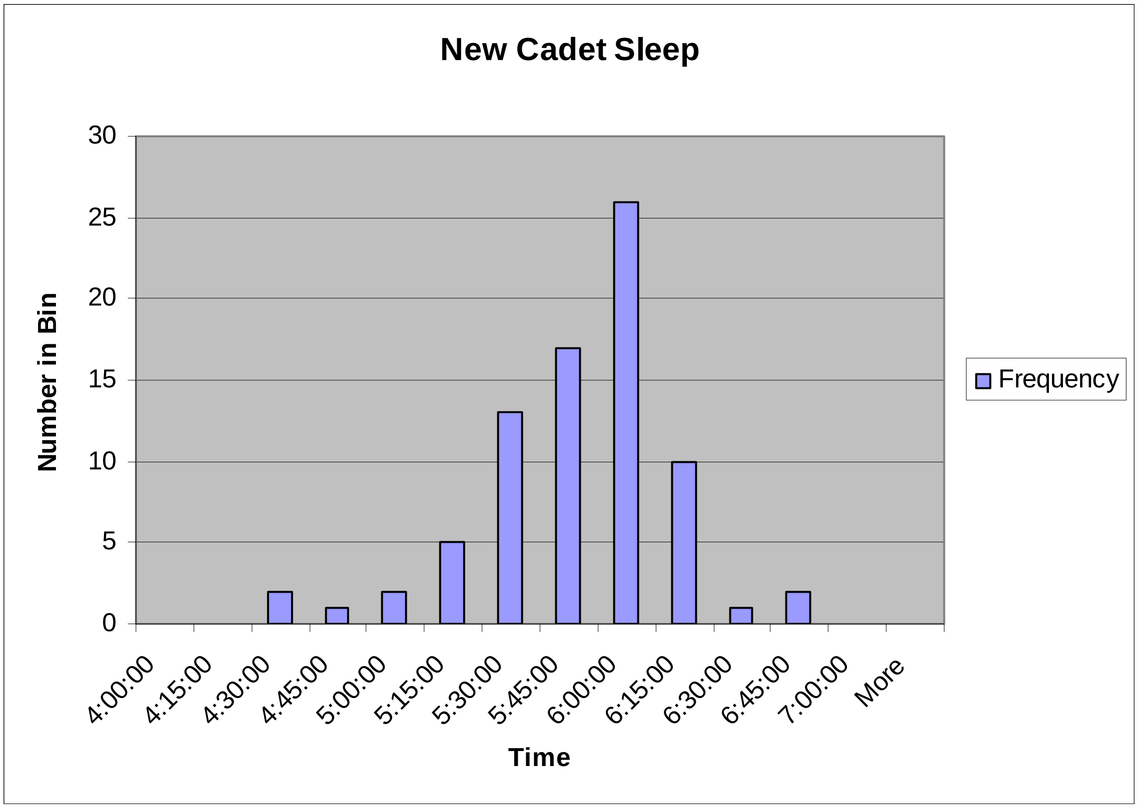


Figure 11. New Cadet Sleep Histogram

In tabular format, the histogram analysis results are:

Bin	*Frequency*
4:00:00	0
4:15:00	0
4:30:00	2
4:45:00	1
5:00:00	2
5:15:00	5
5:30:00	13
5:45:00	17
6:00:00	26
6:15:00	10
6:30:00	1
6:45:00	2
7:00:00	0
More	0

Table 3. New Cadet Bin Population Data

The results were compared to the reported average sleep by the sample in the Pre-CBT Survey. The study sample reported a mean of 7 hours, 46 minutes per night

prior to reporting to CBT. Utilizing data from the Pre-CBT Survey, on average, the New Cadet study sample slept approximately 2 hours, 6 minutes less per night during CBT than prior to reporting to West Point.

2. Gender

Means of the study sample were utilized to conduct the analysis. The data were divided by gender, and descriptive statistics were used to describe nightly sleep.

Female:

Descriptive Statistics	
Mean	5:44:09
Standard Error	0:05:22
Median	5:45:47
Standard Deviation	0:25:45
Sample Variance	0:00:28
Kurtosis	1.050169
Skewness	-0.5468
Range	1:56:55
Minimum	4:39:44
Maximum	6:36:40
Sum	131:55:24
Count	23
Confidence Level(95.0%)	0:11:08

Male:

Descriptive Statistics	
Mean	5:38:12
Standard Error	0:03:17
Median	5:42:29
Standard Deviation	0:24:32
Sample Variance	0:00:25
Kurtosis	1.529892091
Skewness	-0.792349276
Range	2:12:01
Minimum	4:25:57
Maximum	6:37:57
Sum	315:38:59
Count	56

Confidence Level(95.0%)	0:06:34

A comparison plot of the two distributions showing the 25^{th} and 75^{th} percentiles above and below the mean:

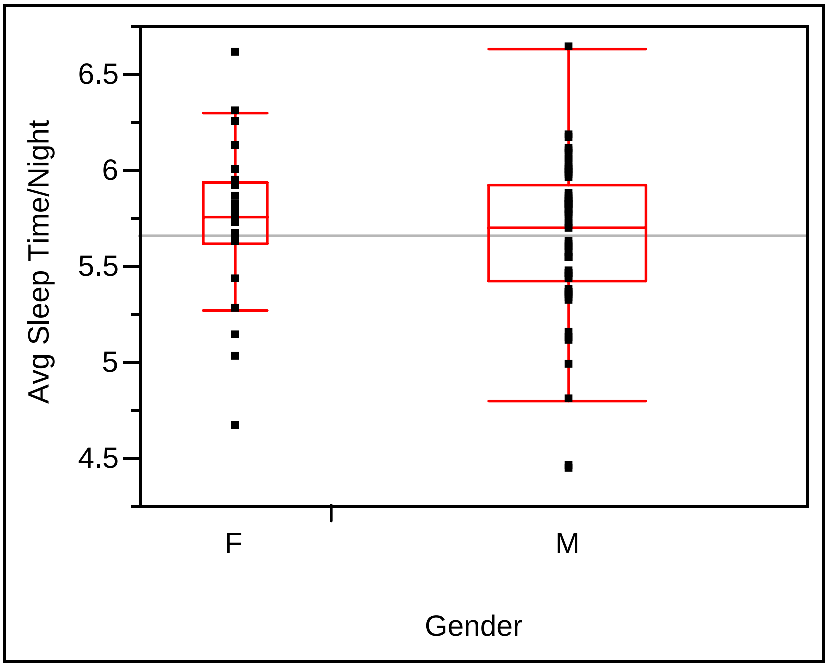


Figure 12. Total Population by Gender Box Plot

Based on Student's t-test ($t = 1.99125$, $\alpha = 0.05$), there is no indication that the female population's higher mean (by approximately 6 minutes) is statistically significant.

3. Ethnic Group

The study population was not stratified by ethnic group. However, post-hoc analysis was done using five groups: Caucasian, African-American, Asian-American, Hispanic, and all other ethnic groups. The groupings are based on the ethnicity data for the study sample. The results are:

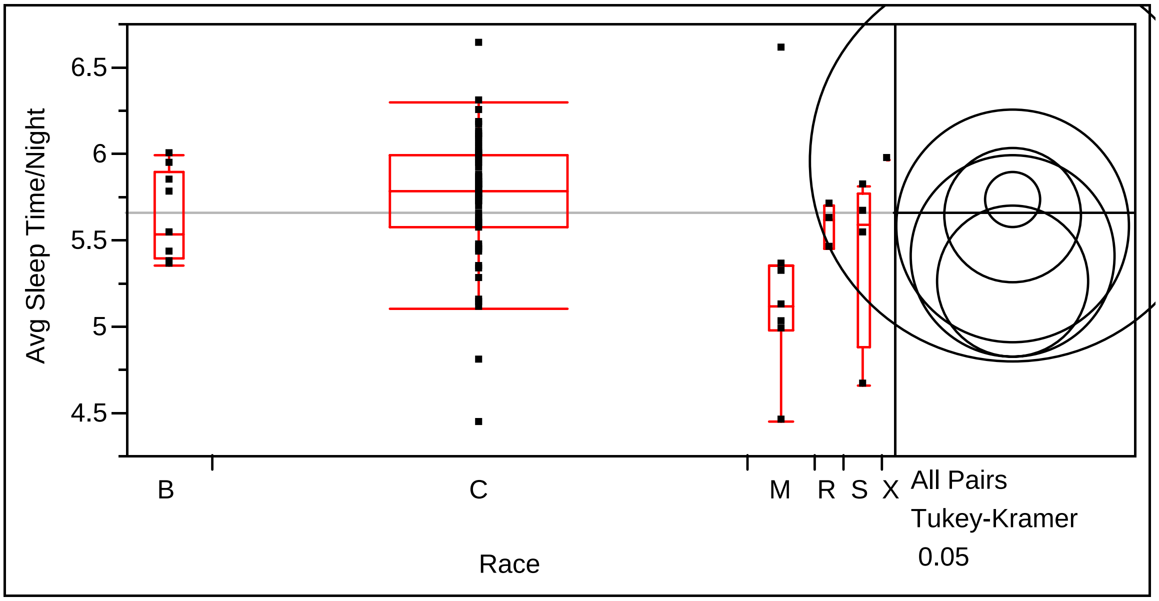


Figure 13. Total Population by Ethnicity Box Plot

Using the Tukey-Kramer HSD test, with α=0.05, there is a statistically significant difference between the Caucasian and Asian-American groups. Asian-Americans as a population slept approximately 30 minutes less per night than Caucasians. There is no statistically significant difference between any other groups.

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.92678	0.05

Abs(Dif)-LSD	X	C	B	R	S	M
X	-1.6513	-0.9557	-0.9107	-0.9747	-0.7608	-0.5506
C	-0.9557	-0.2227	-0.3222	-0.5412	-0.2824	0.0067
B	-0.9107	-0.3222	-0.5504	-0.7250	-0.4771	-0.2108
R	-0.9747	-0.5412	-0.7250	-0.9534	-0.7206	-0.4816
S	-0.7608	-0.2824	-0.4771	-0.7206	-0.8256	-0.5789
M	-0.5506	0.0067	-0.2108	-0.4816	-0.5789	-0.6241

Level			Mean
X	A	B	5.9604167
C	A		5.7379456
B	A	B	5.6403147
R	A	B	5.5868942
S	A	B	5.4157233
M		B	5.2627275

Levels not connected by same letter are significantly different

Table 4. Tukey HSD Means Comparison Table For Ethnicity

An analysis by 1st and 2nd Detail was conducted to see if the difference continued. While Asian-American New Cadets did achieve less sleep on average than Caucasian New Cadets in both details, there were no statistically significant differences between the populations when examined by detail.

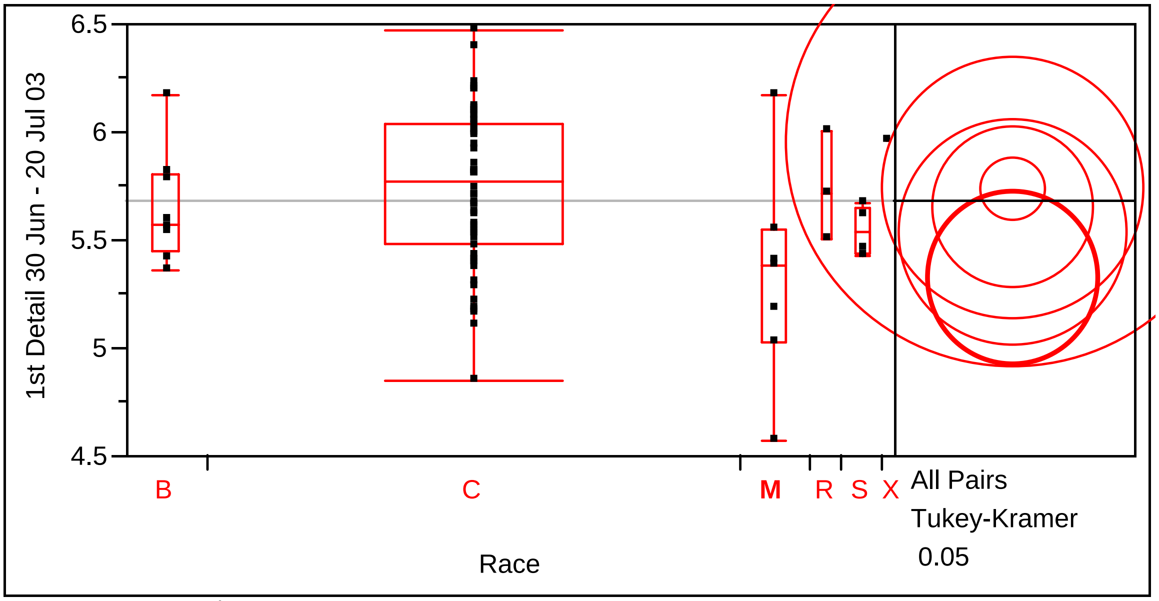


Figure 14. 1st Detail Total Population by Ethnicity Box Plot

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.93132	0.05

Abs(Dif)-LSD	X	R	C	B	S	M
X	-1.4786	-0.9877	-0.8311	-0.8043	-0.7519	-0.4850
R	-0.9877	-0.8536	-0.6159	-0.6227	-0.6010	-0.3083
C	-0.8311	-0.6159	-0.2050	-0.3168	-0.3499	-0.0127
B	-0.8043	-0.6227	-0.3168	-0.5227	-0.5279	-0.2131
S	-0.7519	-0.6010	-0.3499	-0.5279	-0.7393	-0.4396
M	-0.4850	-0.3083	-0.0127	-0.2131	-0.4396	-0.5588

Level		Mean
X	A	5.9604167
R	A	5.7409023
C	A	5.7359867
B	A	5.6557524
S	A	5.5434090
M	A	5.3277345

Levels not connected by same letter are significantly different. Missing Rows 4

Table 5. Tukey HSD Means Comparison For Ethnicity in 1st Detail

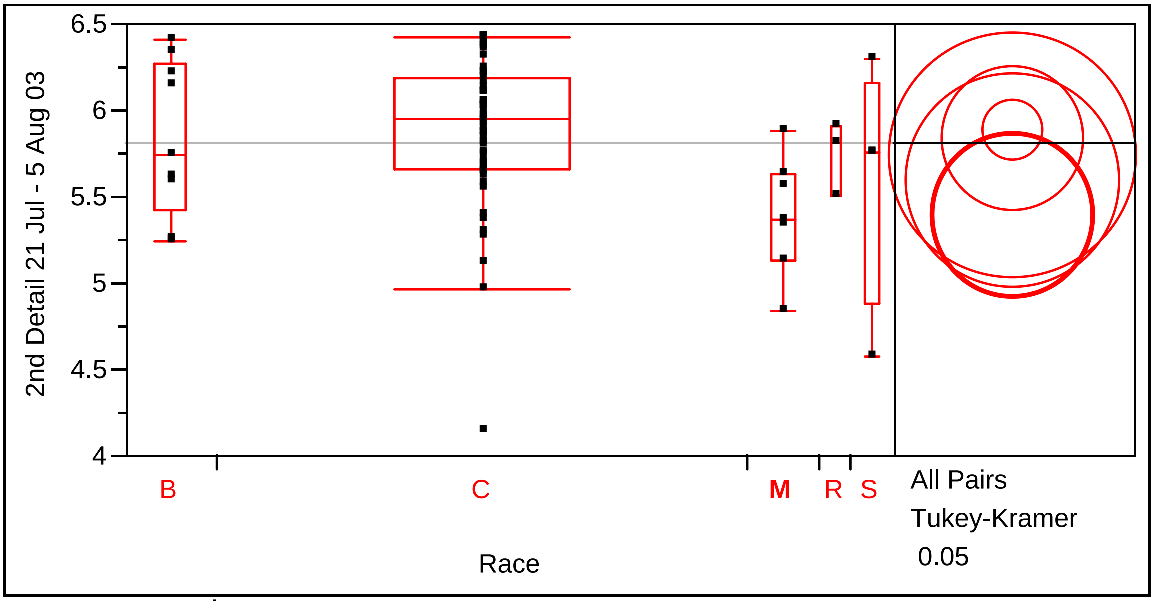


Figure 15. 2nd Detail Total Population by Ethnicity Race Box Plot

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.80122	0.05

Abs(Dif)-LSD	C	B	R	S	M
C	-0.2443	-0.4007	-0.5902	-0.3546	-0.0088
B	-0.4007	-0.5815	-0.7250	-0.5006	-0.1785
R	-0.5902	-0.7250	-1.0071	-0.7988	-0.5054
S	-0.3546	-0.5006	-0.7988	-0.8722	-0.5706
M	-0.0088	-0.1785	-0.5054	-0.5706	-0.6593

Level		Mean
C	A	5.8842960
B	A	5.8390201
R	A	5.7416667
S	A	5.5984375
M	A	5.3958863

Levels not connected by same letter are significantly different. Missing Rows 5

Table 6. Tukey HSD Means Comparison For Ethnicity in 2nd Detail

4. Recruited Athlete

The study sample was divided into two groups, Recruited and Non-Recruited Athletes. West Point uses the term "Corps Squad" to identify intercollegiate athletes. The initial analysis using Student's t-test indicated that

Corps Squad athletes received statistically greater sleep per night than non-recruited cadets.

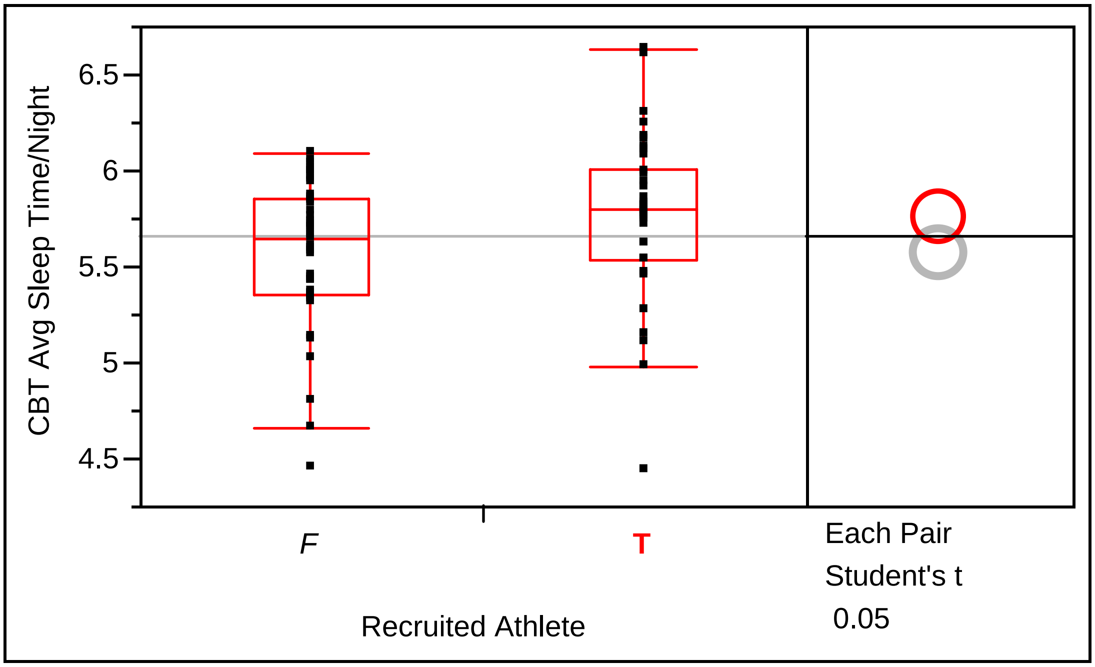


Figure 16. Sample Population by Athlete Box Plot (F = Non-Recruited Athlete, T = Recruited Athlete)

Means Comparisons
Comparisons for each pair using Student's t

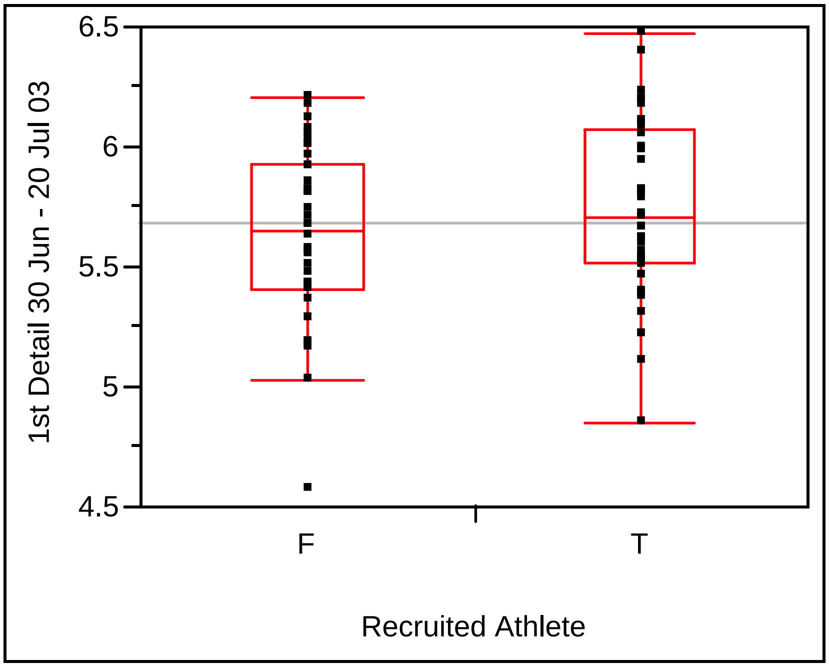
T	Alpha
1.99125	0.05

Abs(Dif)-LSD	T	F
T	-0.18505	0.01584
F	0.01584	-0.17815

Table 7. Student’s t Means Comparison for Athletes

Additional analysis was done by detail. For the 2nd Detail, data were truncated as of 5 August 2003 (March-out to Lake Frederick). This date was used because the fall-season athletes do not participate in all of the Lake Frederick training, and typically get more sleep than their counterparts in the field during this phase. The analysis indicates that the sample’s statistical significance was likely due to the Lake Frederick phase differences between the two groups. When the Lake Frederick phase was

eliminated from the data, no statistically significant difference between the populations resulted.



Missing Rows 4

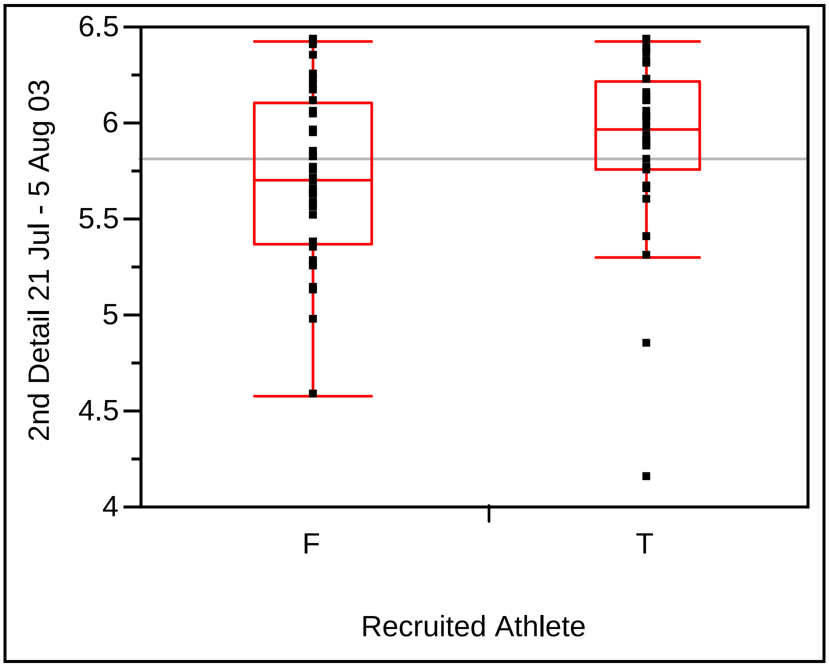
Figure 17. 1st Detail Population by Athlete Box Plot

Means Comparisons

Comparisons for each pair using Student's t

T	Alpha	
1.99300	0.05	
Abs(Dif)-LSD	T	F
T	-0.16908	-0.05061
F	-0.05061	-0.16684

Table 8. Student's t Means Comparison for Athletes, 1st Detail



Missing Rows 5

Figure 18. 2nd Detail Population by Athlete Box Plot

Means Comparisons

Comparisons for each pair using Student's t

t	Alpha
1.99346	0.05

Abs(Dif)-LSD	T	F
T	-0.21419	-0.04168
F	-0.04168	-0.20291

Table 9. Student's t Means Comparison by Athlete, 2nd Detail

5. Company

Companies were compared by detail only, as the cadet leadership changes over between the details. The results show no statistically significant differences between the eight companies (A through H) for either detail.

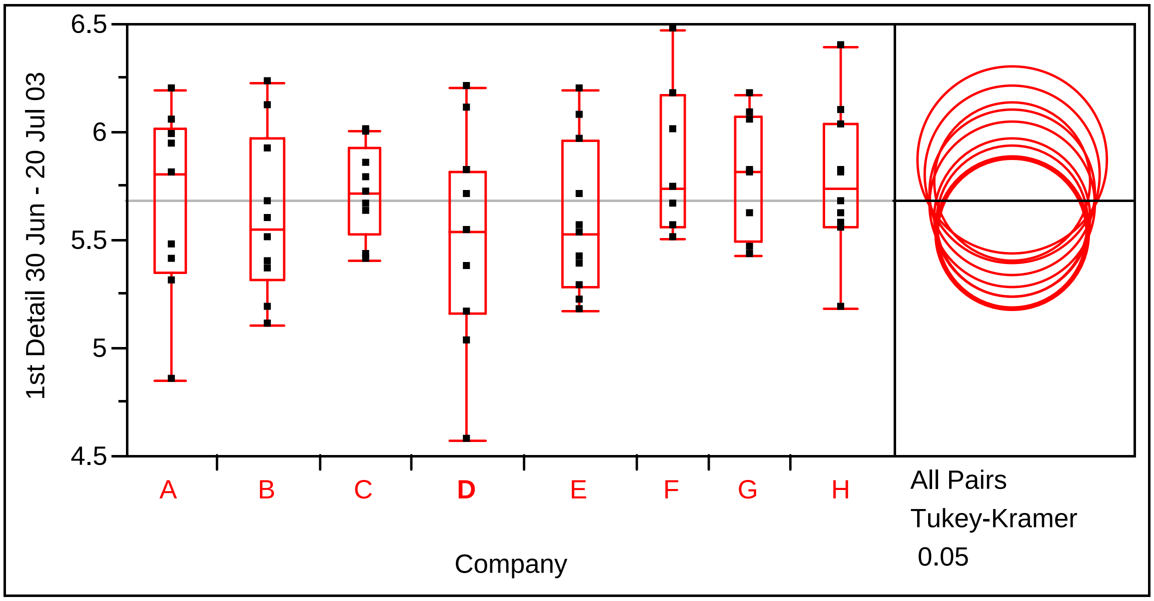


Figure 19. 1st Detail Sample Population by Company Box Plot

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.12871	0.05

Abs(Dif)-LSD	F	G	H	C	A	B	E	D
F	-0.61668	-0.52806	-0.46628	-0.42522	-0.37387	-0.30249	-0.27372	-0.21624
G	-0.52806	-0.57685	-0.51402	-0.47345	-0.42210	-0.35023	-0.32103	-0.26355
H	-0.46628	-0.51402	-0.51595	-0.47617	-0.42482	-0.35216	-0.32227	-0.26479
C	-0.42522	-0.47345	-0.47617	-0.54386	-0.49252	-0.42022	-0.39066	-0.33318
A	-0.37387	-0.42210	-0.42482	-0.49252	-0.54386	-0.47157	-0.44200	-0.38452
B	-0.30249	-0.35023	-0.35216	-0.42022	-0.47157	-0.51595	-0.48606	-0.42859
E	-0.27372	-0.32103	-0.32227	-0.39066	-0.44200	-0.48606	-0.49194	-0.43446
D	-0.21624	-0.26355	-0.26479	-0.33318	-0.38452	-0.42859	-0.43446	-0.49194

Level		Mean
F	A	5.8741319
G	A	5.8050885
H	A	5.7718591
C	A	5.7179350
A	A	5.6665902
B	A	5.6080658
E	A	5.5900402
D	A	5.5325620

Levels not connected by same letter are significantly different. Missing Rows 4

Table 10. Tukey HSD Means Comparison by Company, 1st Detail

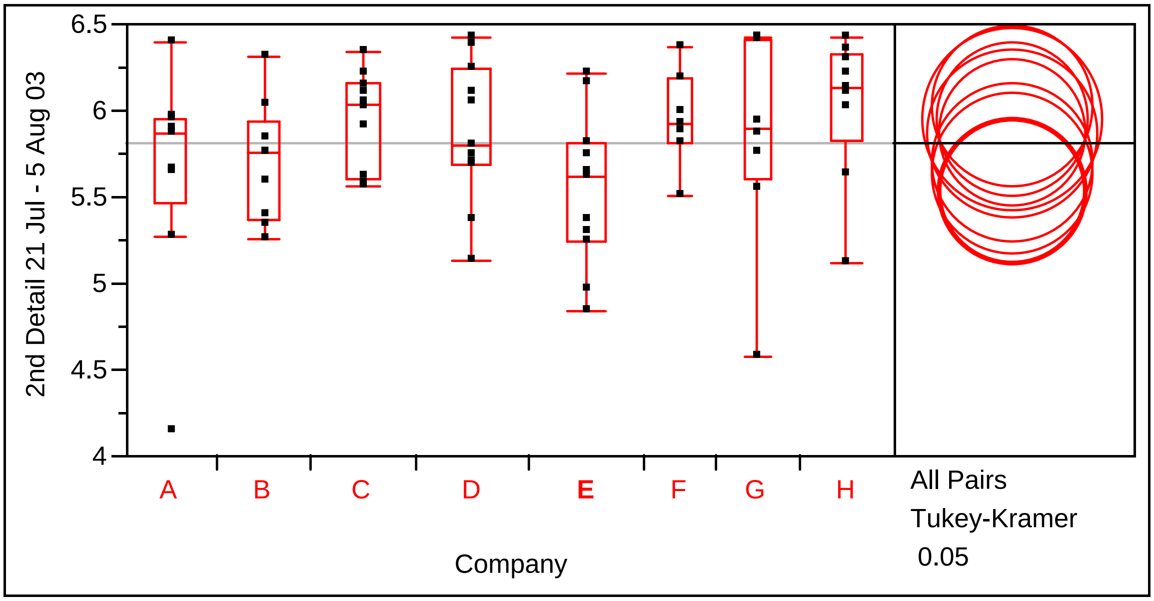


Figure 20. 2nd Detail Sample Population by Company Box Plot

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.13022	0.05

Abs(Dif)-LSD	H	F	C	D	G	B	A	E
H	-0.65553	-0.62432	-0.56022	-0.46776	-0.51339	-0.32546	-0.26835	-0.13105
F	-0.62432	-0.74330	-0.68304	-0.59154	-0.63385	-0.44718	-0.39008	-0.25483
C	-0.56022	-0.68304	-0.62189	-0.52904	-0.57601	-0.38757	-0.33047	-0.19233
D	-0.46776	-0.59154	-0.52904	-0.59295	-0.64110	-0.45221	-0.39511	-0.25624
G	-0.51339	-0.63385	-0.57601	-0.64110	-0.69529	-0.50794	-0.45084	-0.31449
B	-0.32546	-0.44718	-0.38757	-0.45221	-0.50794	-0.65553	-0.59842	-0.46112
A	-0.26835	-0.39008	-0.33047	-0.39511	-0.45084	-0.59842	-0.65553	-0.51822
E	-0.13105	-0.25483	-0.19233	-0.25624	-0.31449	-0.46112	-0.51822	-0.59295

Level		Mean
H	A	6.0308102
F	A	5.9543452
C	A	5.9520972
D	A	5.8735453
G	A	5.8684983
B	A	5.7007390
A	A	5.6436343
E	A	5.5368371

Levels not connected by same letter are significantly different. Missing Rows 5

Table 11. Tukey HSD Means Comparison by Company, 2nd Detail

6. Morningness/Eveningness (M/E)

An analysis utilizing the pre-CBT categories was undertaken. Categories A-E signify a proportional range from morningness (early to bed, early to rise) to eveningness (late to bed, late to rise). No statistically significant differences were found among the five groups.

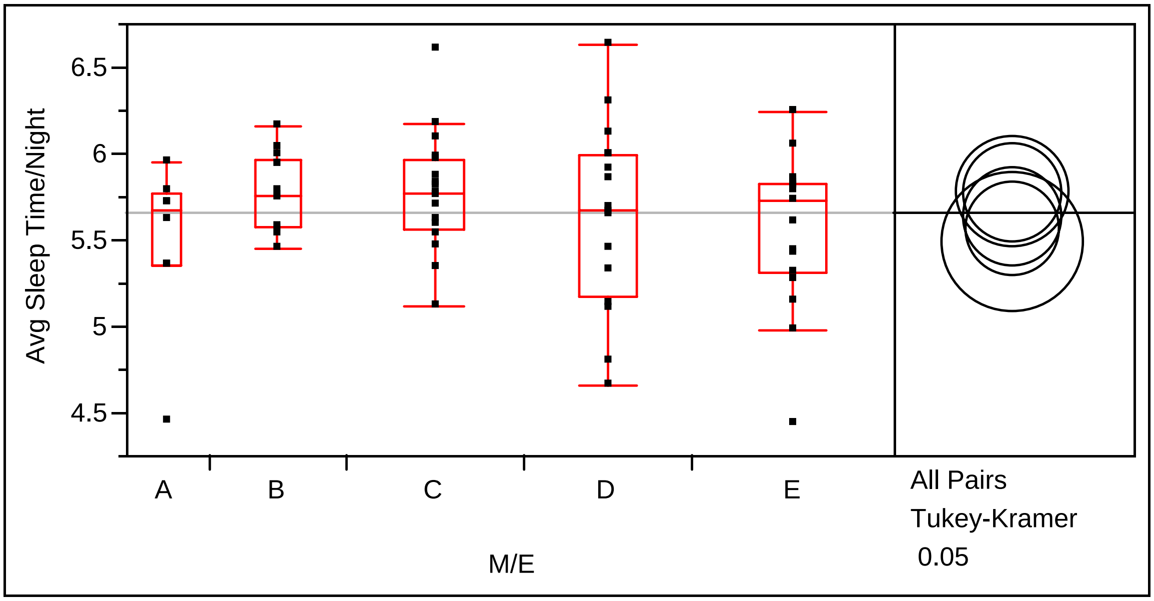


Figure 21. Total Population by M/E Box Plot

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.80232	0.05

Abs(Dif)-LSD	B	C	D	E	A
B	-0.45337	-0.41298	-0.28364	-0.19527	-0.22413
C	-0.41298	-0.39646	-0.26754	-0.17800	-0.21320
D	-0.28364	-0.26754	-0.40866	-0.31938	-0.35319
E	-0.19527	-0.17800	-0.31938	-0.37501	-0.41266
A	-0.22413	-0.21320	-0.35319	-0.41266	-0.57793

Level		Mean
B	A	5.7890880
C	A	5.7761994
D	A	5.6411370
E	A	5.5683142
A	A	5.4938226

Levels not connected by same letter are significantly different

Table 12. Tukey HSD Means Comparison for Sample M/E

7. Age

A Bivariate Fit with linear regression was utilized to determine if age was a factor in New Cadet nightly sleep. The results indicate that age was not a statistically significant factor.

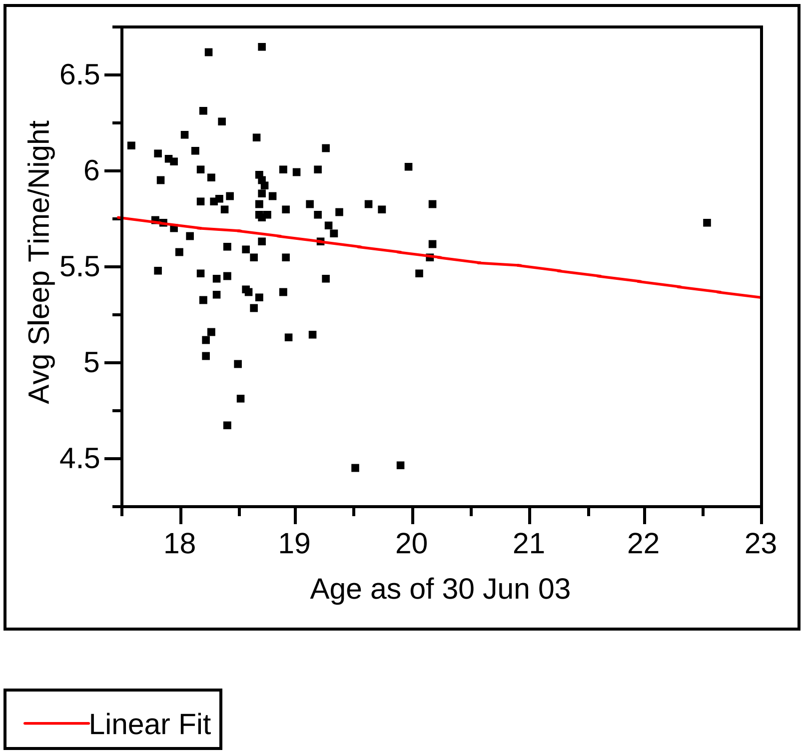


Figure 22. Bivariate Normal Fit by Age

Summary of Fit

RSquare	0.01855
RSquare Adj	0.005804
Root Mean Square Error	0.413331
Mean of Response	5.66548
Observations (or Sum Wgts)	79

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.248638	0.248638	1.4554
Error	77	13.154894	0.170843	Prob > F
C. Total	78	13.403532		0.2314

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7.078837	1.172488	6.04	<.0001
Age as of 30 Jun 03	-0.075387	0.06249	-1.21	0.2314

Table 13. Statistical Summary For Age

B. FAST ANALYSIS

Once the New Cadets with the highest, median, and least average nightly sleep were identified, these data were imported into FAST software program. It is important to recall that the software is programmed using an adult's mean sleep requirement of eight hours per night, not the

higher adolescent range of 8.5-9.25 hours. In addition, the FAST software requires a continuous interval for input, with the default for no data of zero hours of sleep for that 24-hour period. In order to avoid the potential for skewing the data, each subject's mean nightly sleep was substituted for any missing days of data. The result is that the participant's mean nightly sleep does not change, though the standard deviation range becomes smaller. This process of "mean" substitution for missing data is a relatively common and conservative manner in which to handle missing data. In general, data were missing because the New Cadet had removed the watch for data downloading operations. Days with missing data are highlighted by red triangles on the graphical output. In addition, all sleep was rated as "excellent" for all cadets and all nights. This allows for a "best case" result for the FAST output, although the sleep received by cadets at CBT was likely to be somewhat less than optimal. However, given that activity and sleep logs were not used in this study, it was not possible to objectively assess the quality of a particular New Cadet's nightly sleep.

1. FAST Analysis for Maximum Mean Nightly Sleep

The New Cadet with the highest average nightly sleep received an average of approximately 6 hours, 38 minutes per night. One day of data was missing, 11 August 2003 (See FAST output, below).

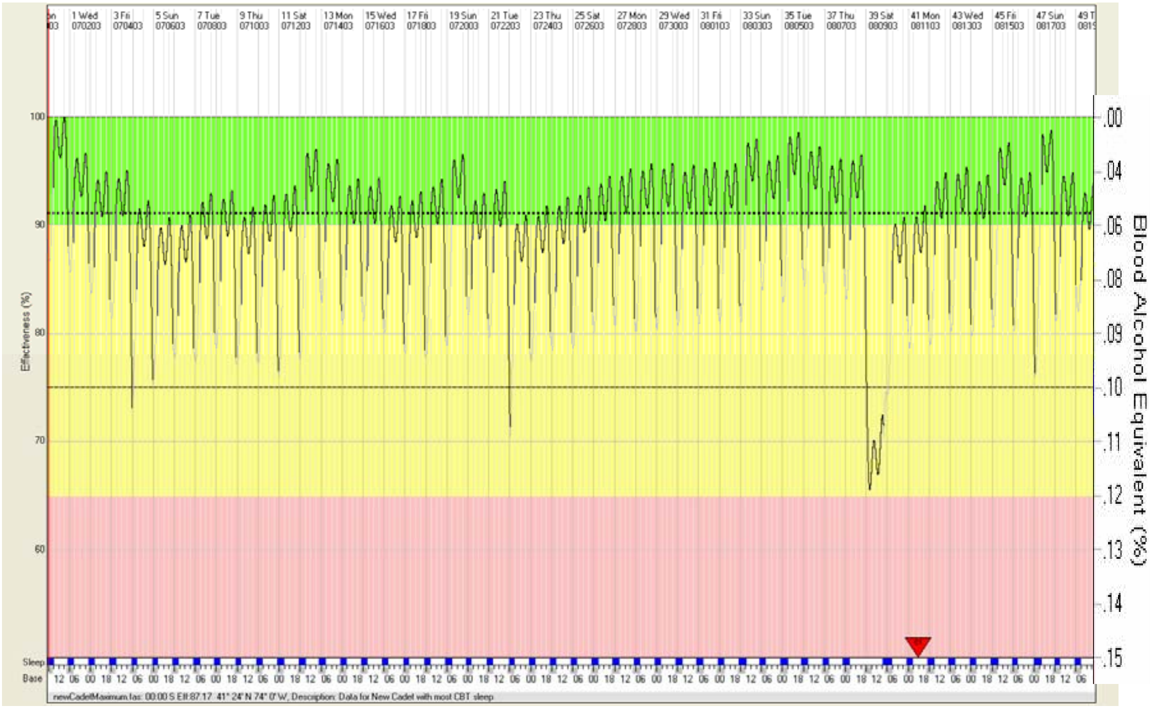


Figure 23. FAST Graphical Output for New Cadet with Maximum Mean Sleep

This participant's mean waking effectiveness (as calculated by the FAST software) is 91.19%, which is shown as the higher of the two horizontal dashed lines. In general, this individual is operating "in the green" for most of CBT.

2. FAST Analysis for Median Mean Nightly Sleep

The median New Cadet slept an average of approximately 5 hours, 44 minutes nightly. Five days of data were missing, and are highlighted by the red triangles on the graphical output. This individual's FAST output is:

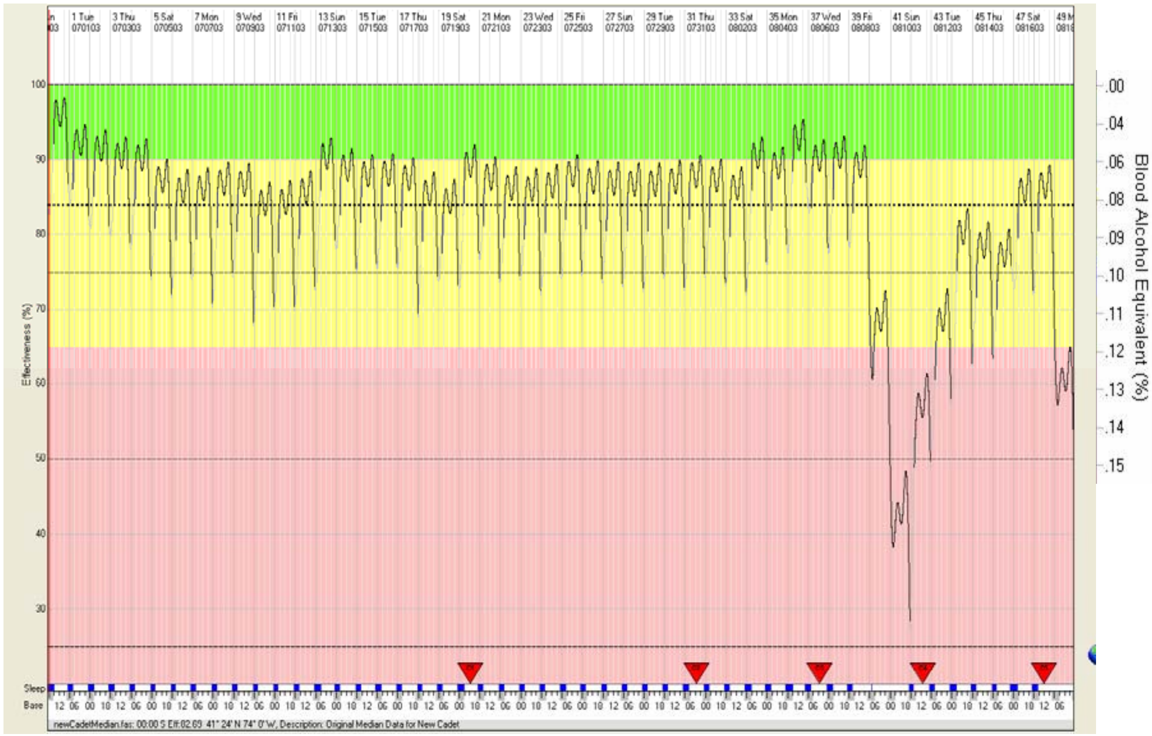


Figure 24. FAST Graphical Output for New Cadet with Median Mean Sleep

Based on the FAST output, this participant's mean waking effectiveness was 84.10%, shown on the upper horizontal dashed line. For most of CBT, this participant was operating in "high yellow", with some daily circadian peaks exceeding the 90% level. Using the blood alcohol equivalent scale, this individual's mean waking effectiveness was just over 0.08%. In some states, this would be enough for a "driving under the influence" charge.

3. FAST Analysis for Minimum Mean Nightly Sleep

The New Cadet with the least amount of mean sleep per night was getting approximately 4 hours, 20 minutes. No days of data were missing for this participant. Of

interest is that this particular individual was a men's football recruit. This New Cadet's output is presented below.

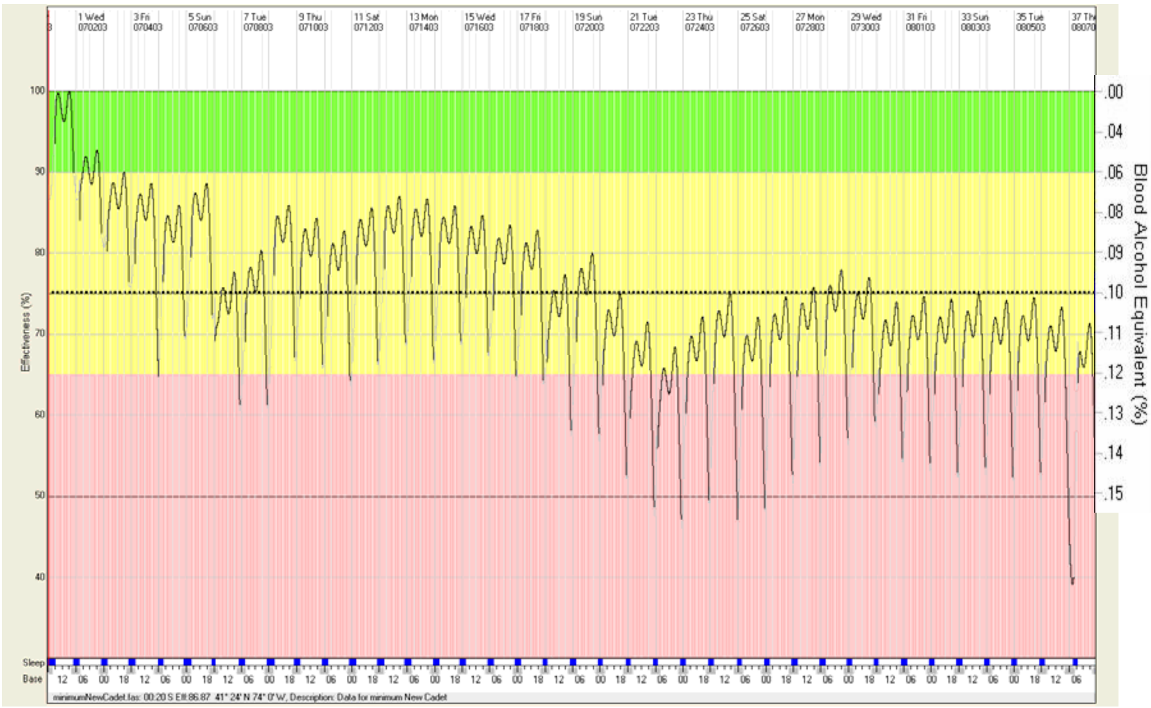


Figure 25. FAST Graphical Output for New Cadet with Minimum Mean Sleep

This New Cadet was above 90% effectiveness for only the first two days during the study period. The participant's mean waking effectiveness was 75.3%, noted by the upper horizontal dashed line on the graph. The blood alcohol equivalence was just slightly less than 0.10% (75% effectiveness). The results show an extremely sleep-deprived individual. It would have been dangerous to allow this person to operate any sort of heavy equipment, to include driving a car. This New Cadet would not have been allowed to pilot any model of US Army aircraft for most of CBT based on this output.

C. HYPOTHETICAL FAST ANALYSIS

Once the initial FAST analysis was complete, a hypothetical analysis was conducted. The purpose of this analysis was to determine how much additional sleep the median participant required to achieve a mean of 90% effectiveness during waking hours. A further objective was to determine what effect this additional sleep would have on the maximum and minimum mean nightly sleep participant's waking effectiveness. For this portion of the study, 15-minute sleep increments were added to each night's sleep for the median participant. This addition included nights for which no sleep data was available. FAST was then recalculated, and the waking effectiveness mean was noted. At 60 minutes of additional nightly sleep, the median New Cadet's mean waking effectiveness was 90.44%. At 45 minutes of additional nightly sleep, the median individual's mean waking effectiveness was 88.48%.

If an additional hour of sleep had been obtained for each New Cadet participating in this study, at least 50% of the participants would have had a predicted waking effectiveness at or above 90%. The blood alcohol equivalence of this effectiveness is 0.06%.

FAST output for each of the three participants follows. The horizontal upper dashed black line reflects the mean waking effectiveness of each individual. The horizontal red line indicates the actual CBT mean waking effectiveness.

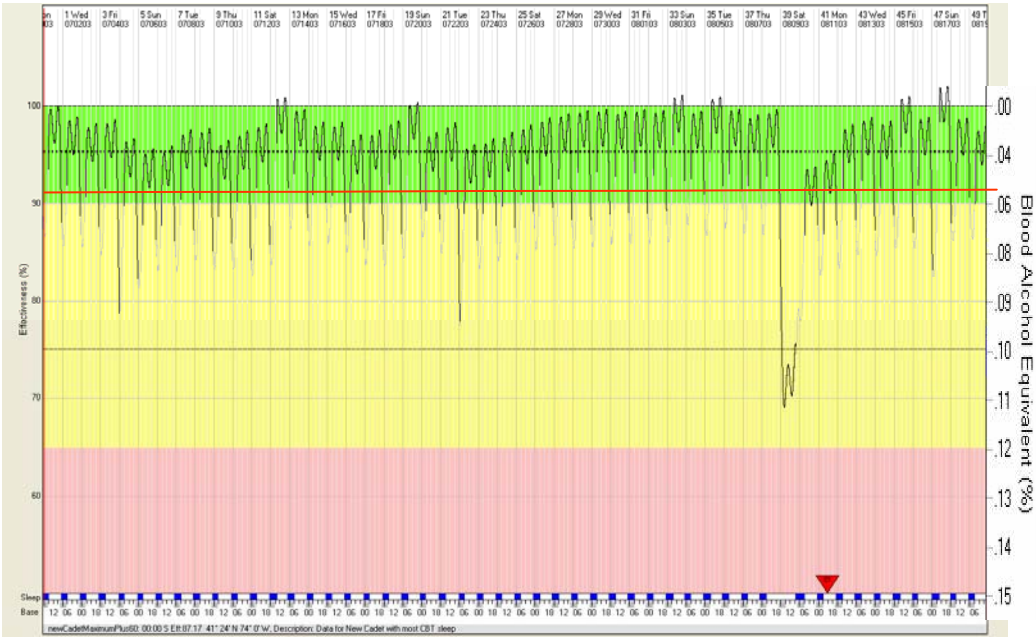


Figure 26. Maximum New Cadet FAST Output after adding 60 minutes to CBT sleep

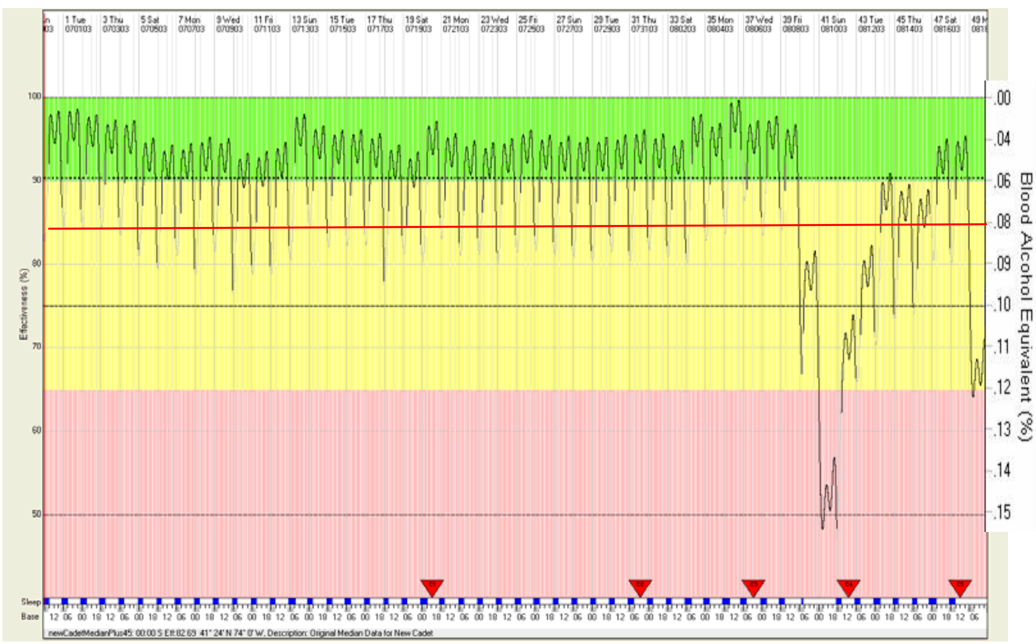


Figure 27. Median New Cadet FAST Output after adding 60 minutes to CBT sleep

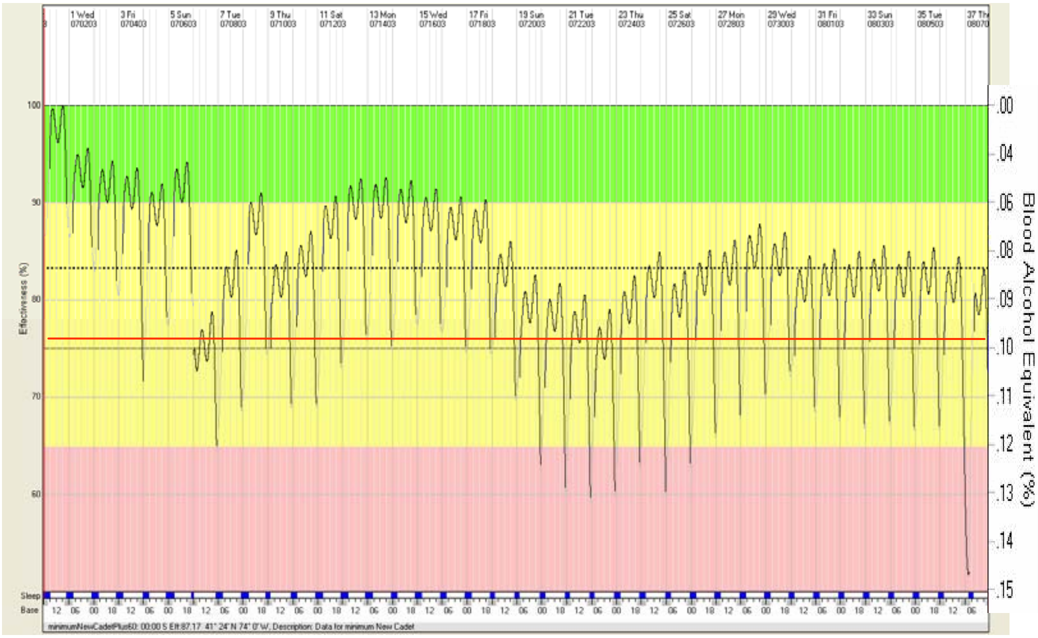


Figure 28. Minimum New Cadet FAST Output after adding 60 minutes to CBT sleep

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V. RECOMMENDATIONS AND CONCLUSIONS

A. CADET BASIC TRAINING

Cadet Basic Training is intentionally designed to be a difficult experience. One goal of CBT is to place stress on the New Cadets. Fatigue is a part of this stress during CBT. It is well understood that the cumulative effects of this stress will lead to some attrition of New Cadets during Cadet Basic Training. For the first time, actigraphy has allowed for the quantification of sleep deprivation and its effects on the New Cadet study population.

In order to lessen the stress due to sleep deprivation-induced fatigue, it is recommended that the New Cadets are allowed an additional hour of sleep throughout the course of CBT. We further recommend that this is accomplished by starting the day’s schedule an hour later than currently practiced. Typically, the beginning of the duty day would then be from 0600-0700, while maintaining the current “lights out” time of 2200. Based on the hypothetical FAST results, the majority of the New Cadet population would then be operating at or above 90% effectiveness during waking hours. This change would likely result in improved overall performance by better skill acquisition and retention in the New Cadet population.

B. ACTIGRAPHY

The major concern with the actigraphy data was an initial lack of a systematic approach that tracked an

individual cadet’s sleep data while allowing that individual to remain anonymous. Matching demographic data with sleep data was crucial to the completion of this study. However, doing so was problematic when it came to data collection and analysis. Names and Social Security Numbers were used to build a spreadsheet with all of the data matched to the applicable New Cadet. At one point, this involved cross-checking four spreadsheets simultaneously. Once that was accomplished, a spreadsheet without identifying data was generated to use in analysis. For future ease in handling data in accordance with commonly accepted guidelines, a combination of a birthday and the last four digits of the Social Security Number should be utilized.

Analyzing the sleep data was fairly straightforward, since no nap analysis was necessary. In Actiware 3.4, nightly sleep and naps must be analyzed separately.

C. FAST SOFTWARE

At the time of this analysis, the FAST software did not accept Actiware sleep data directly. Initially, the data had to be entered by hand, which prevented FAST output for all of the study participants. A work-around using output from Actiware into Excel allowed for a more efficient process, but this is still a less than optimal solution. In future, the development of a capability for FAST to receive data input from Actiware output would greatly speed this process.

Additionally, the sleep and work schedule editing page looks like a spreadsheet, but does not act like one. In order to accomplish any analysis, sleep, wake, and total

sleep times had to be input individually for each day. The ability to accept this data directly from a spreadsheet would have greatly reduced the time required for data input, somewhere on the order of 3 or 4 times less.

D. DATA AVAILABILITY

The ability to correlate sleep with data such as attrition, physical fitness and marksmanship scores, and CBT performance ratings may have been useful, but the lack of an ability to obtain this information without violating anonymity requirements precluded the analysis. The study design was done on short notice, so not thinking of everything necessary for data analysis is common. Recommendation is to come up with a system that will allow tracking of these items by individual, but without violating anonymity requirements.

E. SUMMARY

This study reports the second set of findings of a four-year longitudinal study undertaken to assess the amount of sleep attained by cadets at the Unites States Military Academy. Actigraphy data showed that during CBT, cadets received much less nightly sleep than they reported getting during the 30 days prior to reporting to USMA.

The need for sleep is a combination of the circadian sleep cycle and the homeostatic sleep drive. The need builds with increasing time spent awake. A phase shift in the circadian cycle occurs during adolescence. This phase shift is to a later nightly bed time, as well as a later wake-up time. For these individuals, the highest sleep efficiency is achieved when cadets sleep during a time

frame more in synchronization with this phase shift. Instituting a training schedule that starts later in the morning, and goes later in day would be more in keeping with an adolescent's circadian phase shift. In a study done virtually simultaneously with this one, recruits at the Great Lakes Naval Training Center were allowed eight hours of nightly sleep. However, one group had lights out at 2100, and the other at 2200. The 2200 group attained an average of 22 minutes more sleep per night than their 2100 counterparts (Miller, Baldus, Coard, Sanchez, & Redmond, 2003).

During CBT, the New Cadets are definitely getting less sleep than recommended for their age group. A sleep hygiene education program might well be beneficial for the entire Corps of Cadets. Knowing the signs and dangers of sleep deprivation, as well as countermeasures may assist in both retention and performance throughout their matriculation at USMA.

APPENDIX A. CBT 2003 DATA SET

Subject	Gender	Race	Recruited Athlete	Company	Age as of 30 Jun 03	M/E	1st Detail 30 Jun - 20 Jul	2nd Detail 21 Jul - 5 Aug	CBT Avg Sleep Time/Night	Pre-CBT Reported Sleep
1	M	C	F	D	19.99		5.156481	5.68125	6.00681818	
2	F	M	T	F	18.26	C	6.1725	5.884375	6.61099291	7.5
3	M	C	T	F	18.72	D	5.664167	5.921875	6.63263889	
4	M	C	T	B	19.75	E	5.396491	5.7625	5.77976190	9
5	F	C	T	C	17.6	D	5.995	6.103333	6.11666667	8
6	M	B	T	C	19.39	C	5.782456	6.148889	5.77333333	6.5
7	M	S	T	G	18.65	B	5.460526	5.759375	5.53070175	7
8	F	C	F	H	17.82	E	5.669608	6.097917	5.72777778	8
9	M	C	T	G	19.27		6.054386	6.417778	6.10736434	
10	M	B	F	B	18.92	A	5.36	5.260417	5.35471014	8
11	M	C	F	H	17.97	B	6.025	6.422222	6.04148148	8
12	M	B	F	E	18.58		5.558772	5.244792	5.36276596	
13	M	C	F	B	18.73	C	5.918333	5.844792	5.86205674	5.5
14	M	C	F	A	18.92	D	6.048333	6.395833	5.99618056	9
15	F	C	T	C	18.74	D	5.658772	6.014444	5.91413043	8.5
16	M	C	T	H	19.02	C	6.095	6.129167	5.98222222	8
17	M	M	F	C	18.22	E	5.406349	5.555556	5.30615942	8.5
18	M	C	T	F	18.94	A	5.55625	5.996875	5.78383838	7.5
19	M	C	F	H	18.02	B	5.568333		5.56833333	8.5
20	M	R	F	F	18.21	D	5.506667	5.510417	5.44716312	6
21	F	M	F	D	18.25		5.02807	5.367778	5.02629630	
22	F	B	T	H	17.85	B	5.815	6.210417	5.94042553	8
23	M	C	T	H	18.72	B	5.804167	6.014444	5.74318182	6
24	M	M	T	E	18.53	E	5.380556	4.846875	4.97666667	6.5
25	F	S	F	G	18.43	D	5.43254	4.582292	4.66233333	9.5
26	M	M	F	H	18.61	A	5.5525	5.6375	5.35460993	7
27	M	C	F	E	17.96	D	6.071667	5.364583	5.68262411	8.5
28	F	R	T	C	19.24	A	5.714286	5.90625	5.61895425	9
29	M	C	F	G	17.92	E	5.820833	6.428125	6.05357143	9
30	M	C	T	A	19.53	E	4.85	4.144792	4.43245614	6.5
31	M	C	F	C	18.7	C	5.623148	6.054444	5.75643939	6.5
32	F	C	F	A	18.11	D	5.800833	5.955208	5.64791667	7.5
33	F	S	T	H	18.7	E	5.611404	6.29375	5.80780142	10
34	M	R	F	F	19.29	C	6.001754	5.808333	5.69456522	8
35	M	C	T	D	20.08	B	5.542105	5.792708	5.45507246	6.5
36	M	C	F	G	22.56	A	5.803333	5.935417	5.72163121	5
37	M	C	F	A	18.43	E	5.401587	5.64375	5.43611111	11
38	F	C	T	B	18.66	E	5.5075	5.402083	5.27777778	11
39	F	C	T	A	17.88	A	5.304762	5.872917	5.71666667	5.5
40	F	S	F	B	19.34	D	5.669167	5.758333	5.66205674	6
41	M	B	T	B	18.93	C	5.595833	5.590625	5.53738739	7

42	F	C	T	D	18.81	E	5.707895	6.103125	5.85629630	8
43	M	B	F	G	19.2	B	6.176984	6.410417	5.98986928	6
44	F	C	F	E	19.16	D	5.28254	4.960417	5.12516340	7
45	F	C	F	D	18.4	B	5.821667	5.697917	5.78623188	7
46	M	C	T	E	17.84	C	5.528333	5.642708	5.46631206	9
47	M	C	T	E	18.28	E	5.219167	5.303125	5.14042553	8
48	F	C	T	G	19.2	B		5.867708	5.76296296	9
49	M	C	F	D	18.29	A	6.204762	6.242708	5.95133333	7
50	M	C	F	B	18.45	D	6.12	6.035417	5.85035461	7
51	M	C	T	G	18.72	C	5.611404		5.61140351	8.75
52	M	C	F	G	18.43	C		5.546875	5.58333333	9
53	M	C	F	C	20.2	E	5.851754	5.6125	5.60921986	7
54	F	C	T	D	18.21	D	6.100877	6.416667	5.99037037	8
55	M	C	F	H	18.55	D	5.181746	5.119792	4.80098039	7.25
56	M	C	T	D	19.64	E	5.37193	6.051042	5.80579710	8
57	M	M	F	D	19.91	A	4.566667	5.138095	4.44883721	10
58	M	C	F	E	18.71	D	5.173684	5.815625	5.32427536	8
59	M	C	F	E	18.58	B	5.708333	5.738542	5.57898551	8
60	M	X	F	E	18.7	C	5.960417		5.96041667	7.5
61	M	C	F	E	18.2	C		6.154167	5.82222222	6
62	F	C	F	F	18.73	B	5.74127	6.186667	5.93222222	9
63	F	B	F	E	19.27	E	5.4175	5.6125	5.42872340	4.5
64	F	C	T	A	18.78	B	5.985833	5.960417	5.76312057	7.5
65	M	C	T	G	17.84		6.080702		6.08070175	8
66	M	C	F	A	18.34	E	5.4775	5.276042	5.42517730	9
67	M	C	F	C	18.34	C	5.426316	5.575556	5.34407407	8
68	M	C	T	A	19.13	C	6.196296	5.653125	5.81047619	9
69	M	B	T	D	20.16		5.539474	5.736458	5.52870370	9
70	M	C	T	H	18.06	C	6.395833	6.352083	6.16992754	9
71	M	M	F	B	18.95	C	5.1875	5.341026	5.11553030	7
72	M	C	T	A	18.32	E	5.934167	5.890625	5.82387387	7
73	M	C	T	E	18.67	B	6.189474	6.221875	6.16555556	7
74	M	C	T	D	20.19	E	5.818254	6.38125	5.81797386	
75	M	C	F	C	18.16	C	6.003333	6.213333	6.09469697	7.5
76	F	C	T	F	18.23	D	6.476316	6.371875	6.30283688	8
77	M	C	T	B	18.25	D	5.1025		5.10250000	6.75
78	M	B	F	C	18.37	E		6.336667	5.84691358	8
79	F	C	T	B	18.39	E	6.223333	6.311458	6.24548611	10

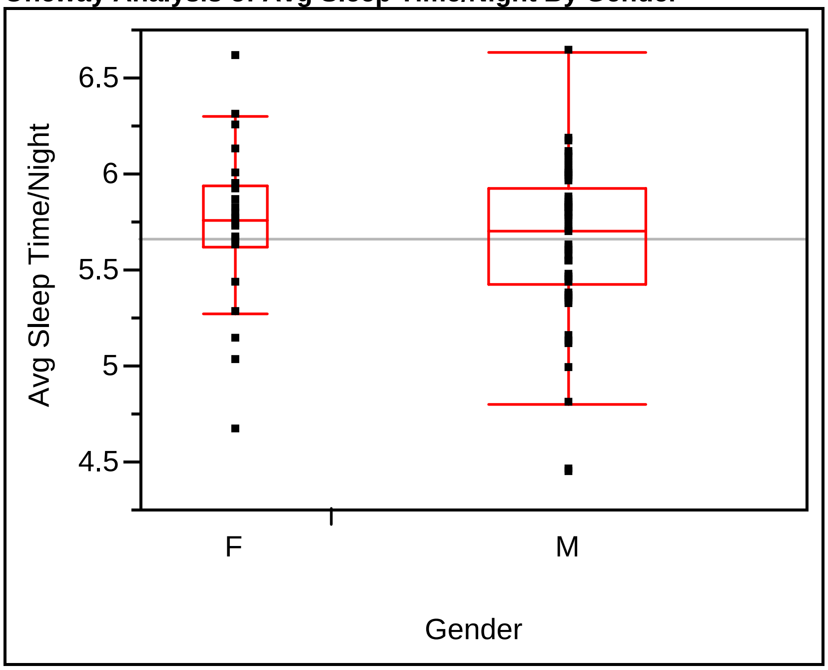
Note: Average Nightly Sleep calculated by using Actiware 3.4, Mini Mitter Co., Inc., Bend, Oregon 97701

APPENDIX B. STATISTICAL ANALYSIS OUTPUT BY POPULATION

Note: JMP IN™, release 5.1 software was utilized to conduct the statistical analysis

Fit Y by X Group

Oneway Analysis of Avg Sleep Time/Night By Gender

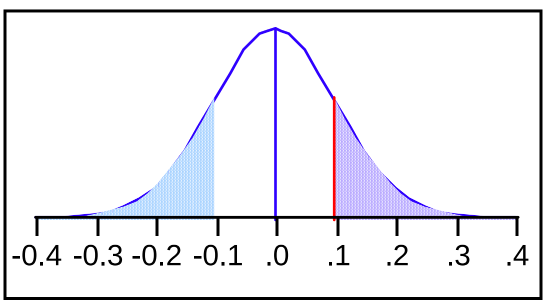


t Test

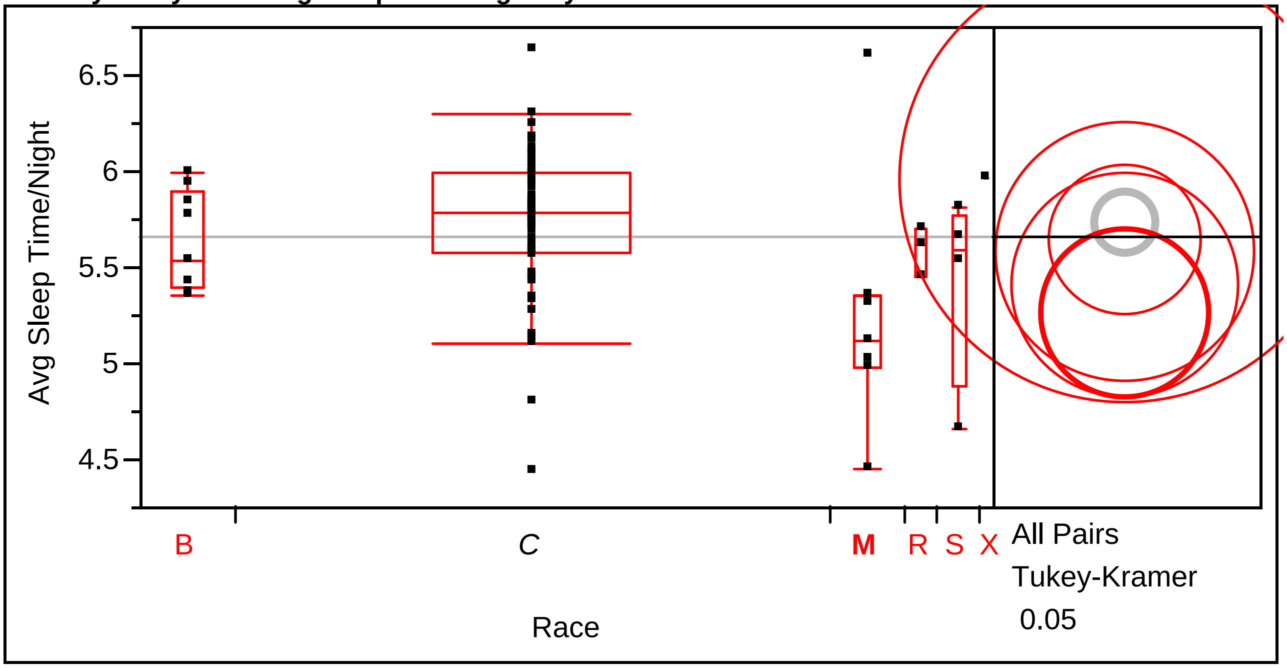
F-M

Assuming unequal variances

Difference	0.09919	t Ratio	0.946004
Std Err Dif	0.10485	DF	39.26382
Upper CL Dif	0.31123	Prob > |t|	0.3499
Lower CL Dif	-0.11285	Prob > t	0.1750
Confidence	0.95	Prob < t	0.8250



Oneway Analysis of Avg Sleep Time/Night By Race



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.92678	0.05

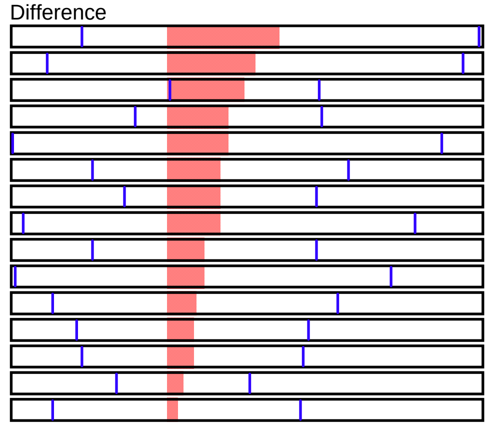
Abs(Dif)-LSD	X	C	B	R	S	M
X	-1.6513	-0.9557	-0.9107	-0.9747	-0.7608	-0.5506
C	-0.9557	-0.2227	-0.3222	-0.5412	-0.2824	0.0067
B	-0.9107	-0.3222	-0.5504	-0.7250	-0.4771	-0.2108
R	-0.9747	-0.5412	-0.7250	-0.9534	-0.7206	-0.4816
S	-0.7608	-0.2824	-0.4771	-0.7206	-0.8256	-0.5789
M	-0.5506	0.0067	-0.2108	-0.4816	-0.5789	-0.6241

Level			Mean
X	A	B	5.9604167
C	A		5.7379456
B	A	B	5.6403147
R	A	B	5.5868942
S	A	B	5.4157233
M		B	5.2627275

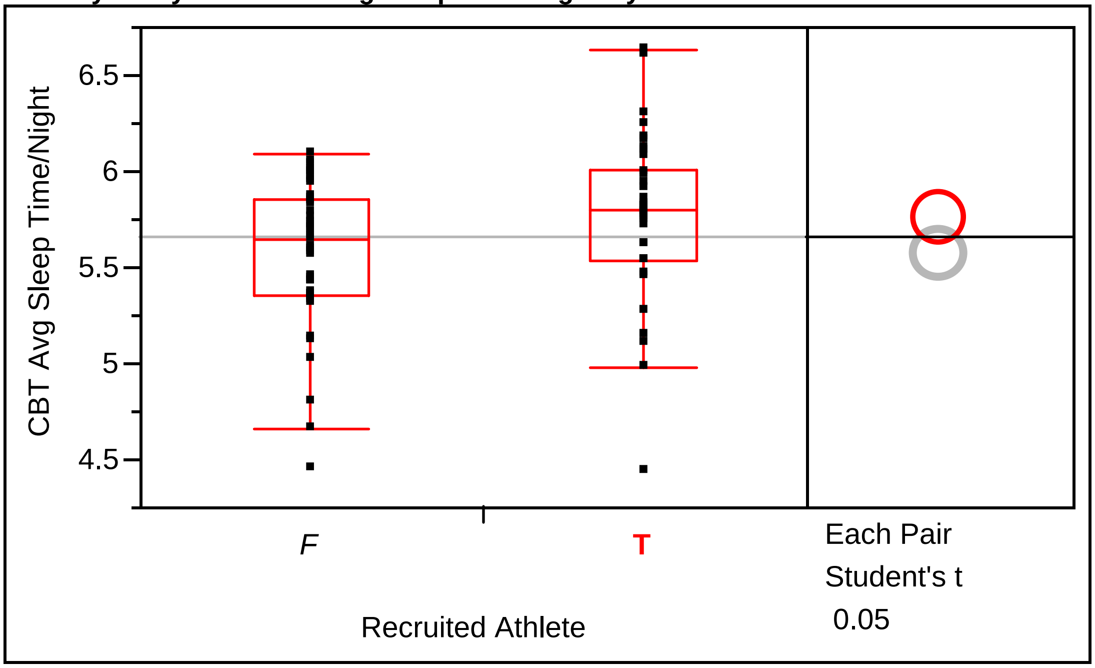
Levels not connected by same letter are significantly different

Level	- Level	Difference	Lower CL	Upper CL
X	M	0.6976891	-0.550556	1.945934
X	S	0.5446934	-0.760752	1.850139
C	M	0.4752181	0.006654	0.943783
B	M	0.3775872	-0.210841	0.966015
X	R	0.3735225	-0.974736	1.721781
R	M	0.3241667	-0.481572	1.129905
C	S	0.3222223	-0.282448	0.926892
X	B	0.3201020	-0.910684	1.550888
B	S	0.2245914	-0.477065	0.926247
X	C	0.2224710	-0.955722	1.400664
R	S	0.1711709	-0.720618	1.062960
S	M	0.1529958	-0.578853	0.884844
C	R	0.1510514	-0.541219	0.843322
C	B	0.0976309	-0.322216	0.517478
B	R	0.0534205	-0.724997	0.831838

Difference



Oneway Analysis of CBT Avg Sleep Time/Night By Recruited Athlete



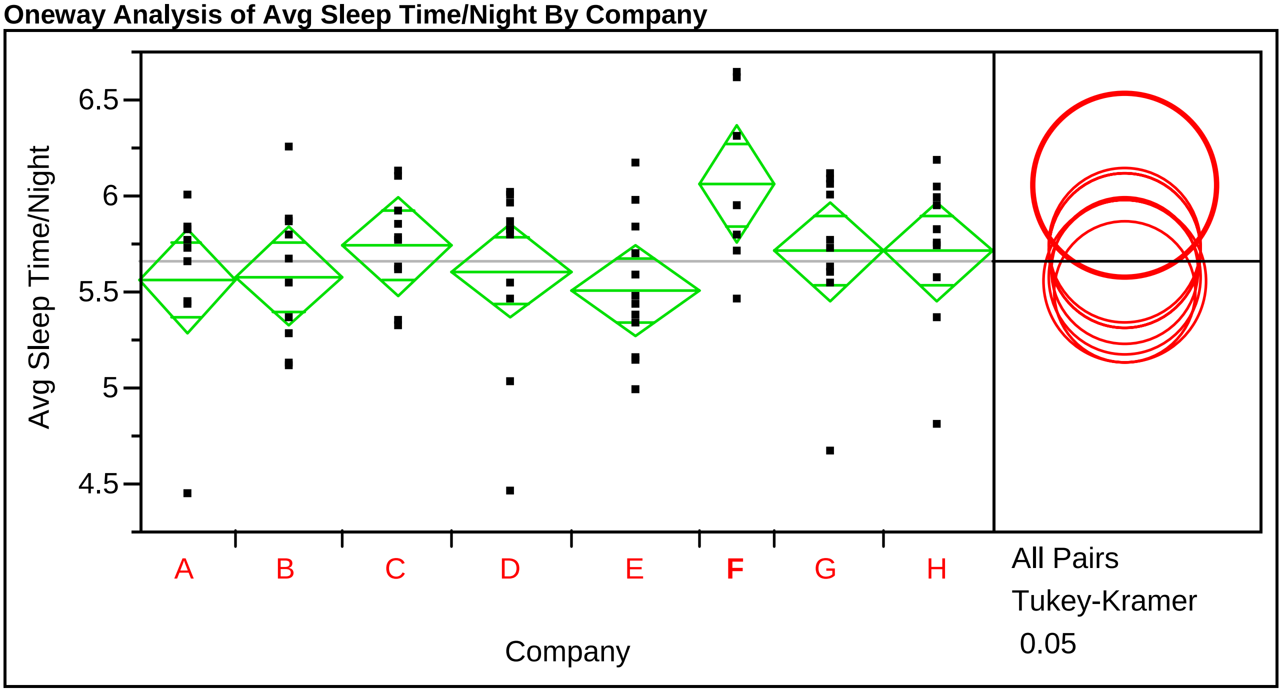
Means Comparisons

Comparisons for each pair using Student's t

t	Alpha
1.99125	0.05

Abs(Dif)-LSD	T	F
T	-0.18505	0.01584
F	0.01584	-0.17815

Oneway Analysis of Avg Sleep Time/Night By Company



Oneway Anova
Summary of Fit

Rsquare	0.126939
Adj Rsquare	0.040863
Root Mean Square Error	0.405978
Mean of Response	5.66548
Observations (or Sum Wgts)	79

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Company	7	1.701435	0.243062	1.4747	0.1903
Error	71	11.702097	0.164818		
C. Total	78	13.403532			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
A	9	5.56133	0.13533	5.2915	5.8312
B	10	5.57876	0.12838	5.3228	5.8347
C	10	5.73806	0.12838	5.4821	5.9940
D	11	5.60670	0.12241	5.3626	5.8508
E	12	5.50284	0.11720	5.2692	5.7365
F	7	6.05775	0.15345	5.7518	6.3637
G	10	5.71039	0.12838	5.4544	5.9664
H	10	5.71367	0.12838	5.4577	5.9697

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.12312	0.05

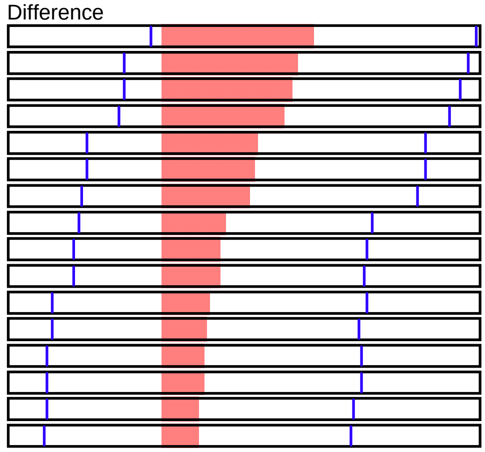
Abs(Dif)-LSD	F	C	H	G	D	B	A	E
F	-0.67773	-0.30514	-0.28076	-0.27747	-0.16198	-0.14585	-0.14255	-0.04811
C	-0.30514	-0.56703	-0.54265	-0.53936	-0.42264	-0.40773	-0.40584	-0.30768
H	-0.28076	-0.54265	-0.56703	-0.56374	-0.44702	-0.43212	-0.43022	-0.33206
G	-0.27747	-0.53936	-0.56374	-0.56703	-0.45031	-0.43540	-0.43351	-0.33535
D	-0.16198	-0.42264	-0.44702	-0.45031	-0.54064	-0.52605	-0.52451	-0.42540
B	-0.14585	-0.40773	-0.43212	-0.43540	-0.52605	-0.56703	-0.56514	-0.46697
A	-0.14255	-0.40584	-0.43022	-0.43351	-0.52451	-0.56514	-0.59770	-0.50061
E	-0.04811	-0.30768	-0.33206	-0.33535	-0.42540	-0.46697	-0.50061	-0.51762

Level		Mean
F	A	6.0577511
C	A	5.7380588
H	A	5.7136741
G	A	5.7103873
D	A	5.6067028
B	A	5.5787622
A	A	5.5613310
E	A	5.5028447

Levels not connected by same letter are significantly different

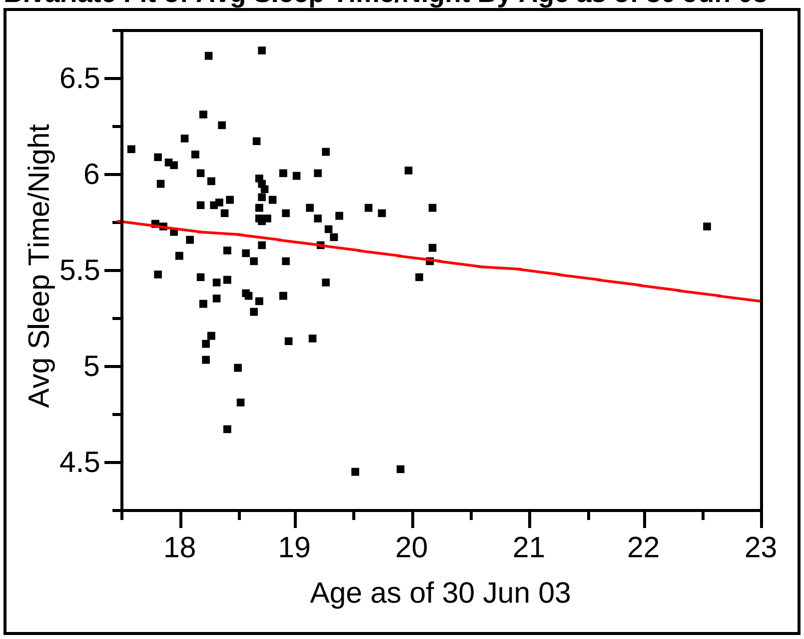
Level	- Level	Difference	Lower CL	Upper CL
F	E	0.5549064	-0.048108	1.157921
F	A	0.4964201	-0.142550	1.135390
F	B	0.4789889	-0.145847	1.103825
F	D	0.4510483	-0.161982	1.064078
F	G	0.3473638	-0.277472	0.972200
F	H	0.3440769	-0.280759	0.968913
F	C	0.3196923	-0.305144	0.944529
C	E	0.2352141	-0.307676	0.778104
H	E	0.2108294	-0.332060	0.753719
G	E	0.2075426	-0.335347	0.750432
C	A	0.1767278	-0.405840	0.759295
C	B	0.1592966	-0.407733	0.726326
H	A	0.1523431	-0.430224	0.734911
G	A	0.1490563	-0.433511	0.731624
H	B	0.1349120	-0.432118	0.701942
G	B	0.1316251	-0.435405	0.698655

Difference



Level	- Level	Difference	Lower CL	Upper CL	Difference
C	D	0.1313560	-0.422637	0.685349	
H	D	0.1069714	-0.447021	0.660964	
D	E	0.1038581	-0.425400	0.633116	
G	D	0.1036845	-0.450308	0.657677	
B	E	0.0759175	-0.466972	0.618807	
A	E	0.0584863	-0.500613	0.617585	
D	A	0.0453718	-0.524515	0.615258	
D	B	0.0279406	-0.526052	0.581933	
C	G	0.0276715	-0.539358	0.594701	
C	H	0.0243847	-0.542645	0.591414	
B	A	0.0174312	-0.565136	0.599999	
H	G	0.0032869	-0.563743	0.570317	

Bivariate Fit of Avg Sleep Time/Night By Age as of 30 Jun 03



Linear Fit

Linear Fit

Avg Sleep Time/Night = 7.078837 - 0.0753867 Age as of 30 Jun 03

Summary of Fit

RSquare	0.01855
RSquare Adj	0.005804
Root Mean Square Error	0.413331
Mean of Response	5.66548
Observations (or Sum Wgts)	79

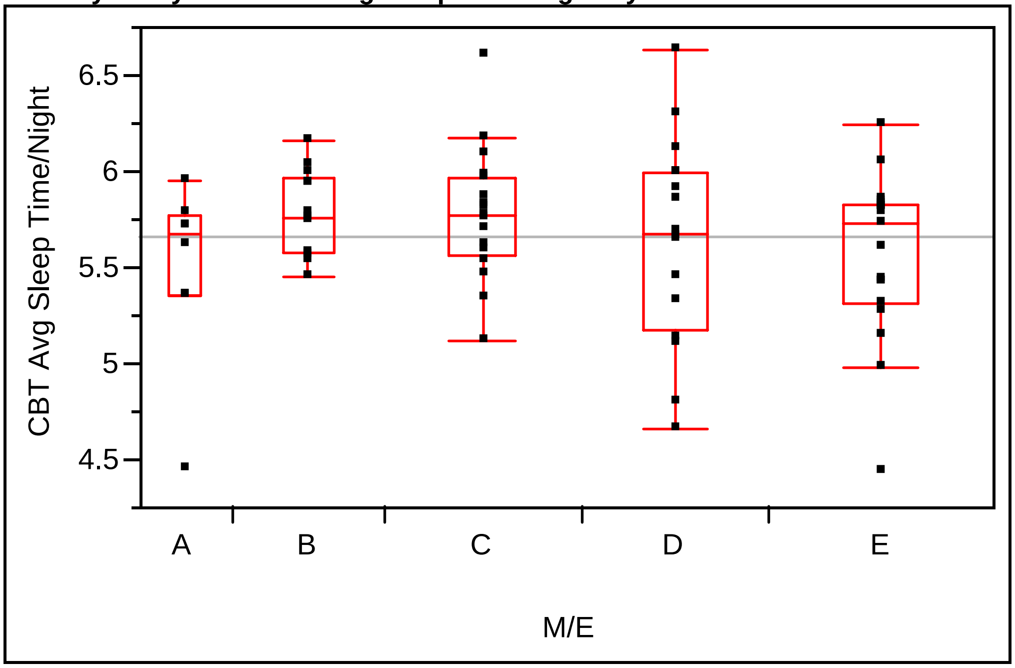
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.248638	0.248638	1.4554
Error	77	13.154894	0.170843	Prob > F
C. Total	78	13.403532		0.2314

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7.078837	1.172488	6.04	<.0001
Age as of 30 Jun 03	-0.075387	0.06249	-1.21	0.2314

Oneway Analysis of CBT Avg Sleep Time/Night By M/E



Missing Rows 6

Oneway Anova

Summary of Fit

Rsquare	0.067049
Adj Rsquare	0.012169
Root Mean Square Error	0.412468
Mean of Response	5.663839
Observations (or Sum Wgts)	73

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
M/E	4	0.831423	0.207856	1.2217	0.3098
Error	68	11.568830	0.170130		
C. Total	72	12.400253			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
A	8	5.49382	0.14583	5.2028	5.7848
B	13	5.78909	0.11440	5.5608	6.0174
C	17	5.77620	0.10004	5.5766	5.9758
D	16	5.64114	0.10312	5.4354	5.8469
E	19	5.56831	0.09463	5.3795	5.7571

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

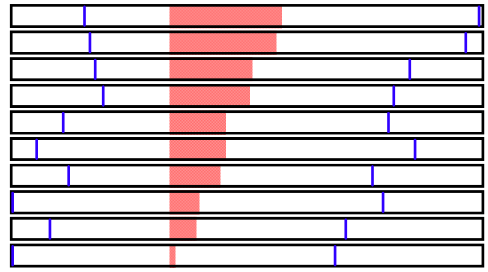
q*	Alpha
2.80232	0.05

Abs(Dif)-LSD	B	C	D	E	A
B	-0.45337	-0.41298	-0.28364	-0.19527	-0.22413
C	-0.41298	-0.39646	-0.26754	-0.17800	-0.21320
D	-0.28364	-0.26754	-0.40866	-0.31938	-0.35319
E	-0.19527	-0.17800	-0.31938	-0.37501	-0.41266
A	-0.22413	-0.21320	-0.35319	-0.41266	-0.57793

Level		Mean
B	A	5.7890880
C	A	5.7761994
D	A	5.6411370
E	A	5.5683142
A	A	5.4938226

Levels not connected by same letter are significantly different

Level	- Level	Difference	Lower CL	Upper CL	Difference
B	A	0.2952654	-0.224133	0.8146643	
C	A	0.2823768	-0.213197	0.7779509	
B	E	0.2207738	-0.195266	0.6368133	
C	E	0.2078852	-0.178000	0.5937703	
B	D	0.1479511	-0.283643	0.5795450	
D	A	0.1473143	-0.353191	0.6478196	
C	D	0.1350624	-0.267544	0.5376687	
E	A	0.0744916	-0.412664	0.5616477	
D	E	0.0728227	-0.319375	0.4650206	
B	C	0.0128886	-0.412977	0.4387542	



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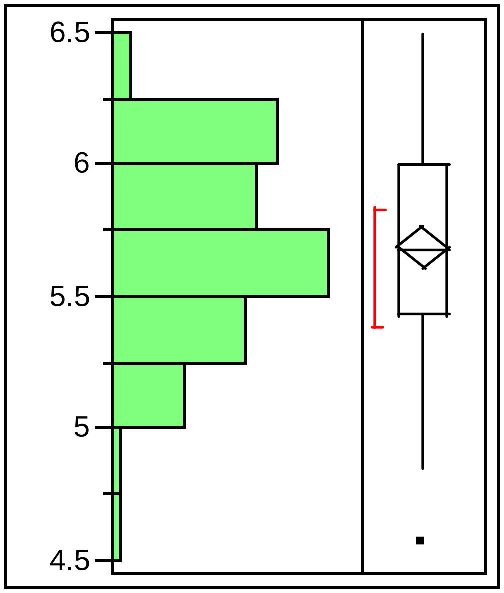
APPENDIX C. STATISTICAL ANALYSIS OUTPUT BY DETAIL

1st Detail (30 Jun – 20 Jul 03) Distribution and Box Plots

Distributions
1st Detail 30 Jun - 20 Jul 03



Quantiles

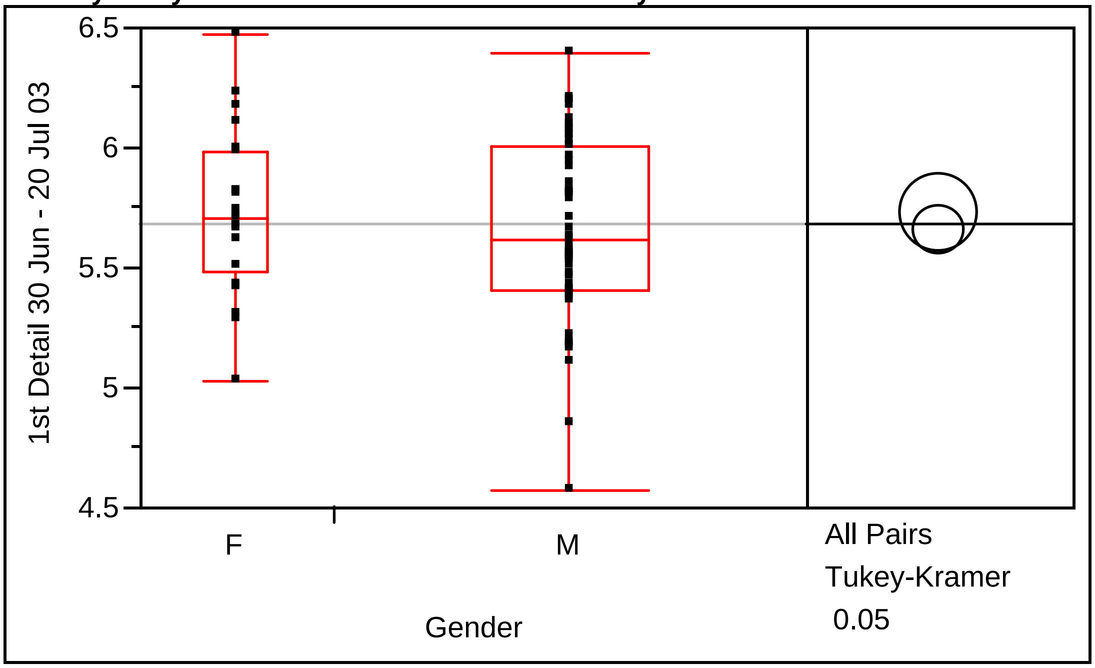
100.0%	maximum	6.4763
99.5%		6.4763
97.5%		6.4039
90.0%		6.1743
75.0%	quartile	5.9950
50.0%	median	5.6692
25.0%	quartile	5.4263
10.0%		5.1852
2.5%		4.8217
0.5%		4.5667
0.0%	minimum	4.5667

Moments

Mean	5.6822431
Std Dev	0.3671981
Std Err Mean	0.0424004
upper 95% Mean	5.7667277
lower 95% Mean	5.5977585
N	75

Fit Y by X Group

Oneway Analysis of 1st Detail 30 Jun - 20 Jul 03 By Gender



Missing Rows 4

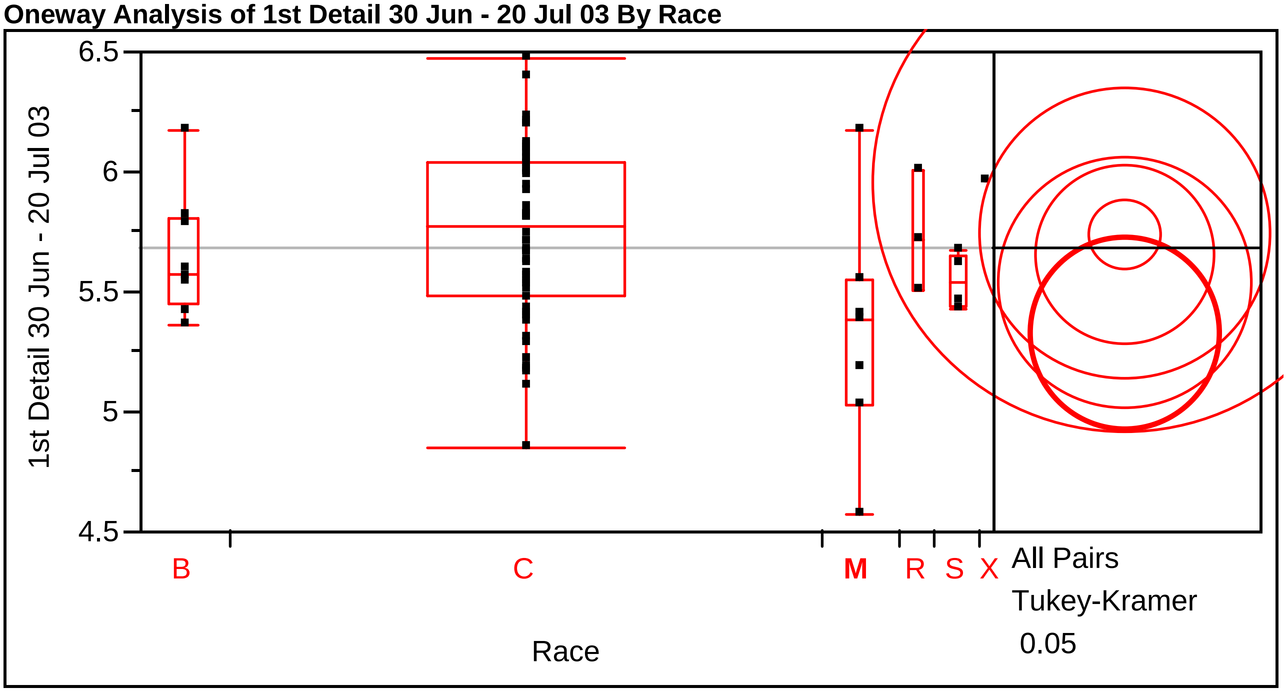
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
1.99308	0.05

Abs(Dif)-LSD	F	M
F	-0.22126	-0.11360
M	-0.11360	-0.14255

Oneway Analysis of 1st Detail 30 Jun - 20 Jul 03 By Race



Missing Rows 4

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.93132	0.05

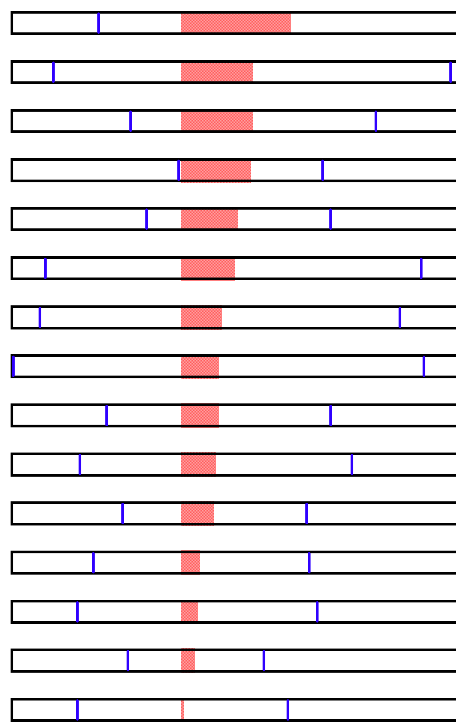
Abs(Dif)-LSD	X	R	C	B	S	M
X	-1.4786	-0.9877	-0.8311	-0.8043	-0.7519	-0.4850
R	-0.9877	-0.8536	-0.6159	-0.6227	-0.6010	-0.3083
C	-0.8311	-0.6159	-0.2050	-0.3168	-0.3499	-0.0127
B	-0.8043	-0.6227	-0.3168	-0.5227	-0.5279	-0.2131
S	-0.7519	-0.6010	-0.3499	-0.5279	-0.7393	-0.4396
M	-0.4850	-0.3083	-0.0127	-0.2131	-0.4396	-0.5588

Level	Mean
X	5.9604167
R	5.7409023
C	5.7359867
B	5.6557524
S	5.5434090
M	5.3277345

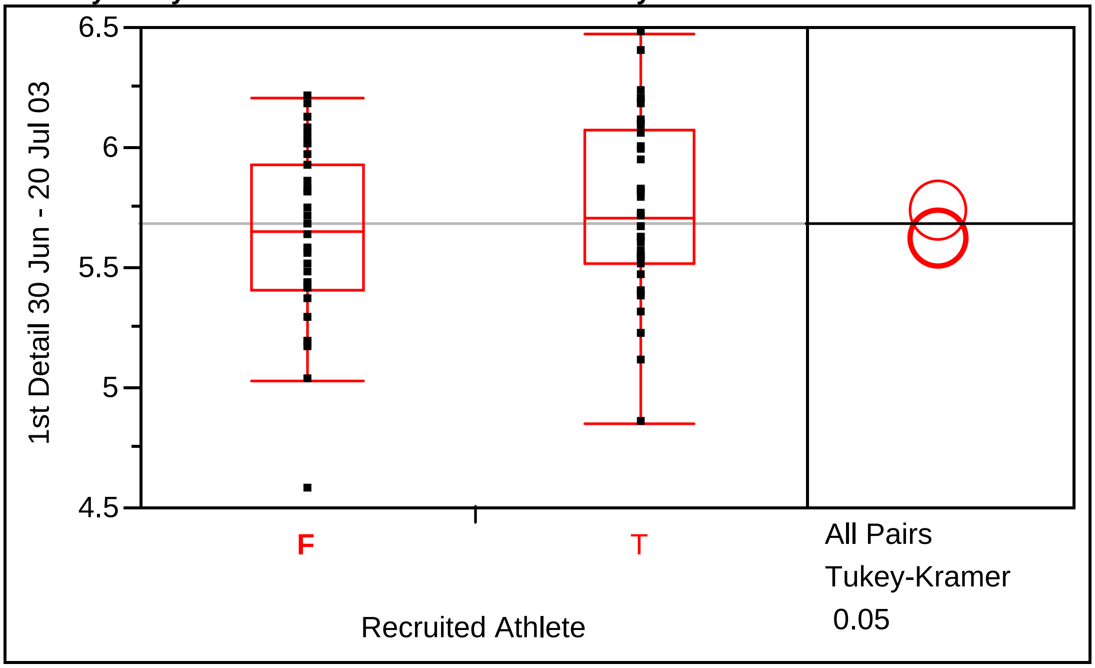
Levels not connected by same letter are significantly different

Level	- Level	Difference	Lower CL	Upper CL
X	M	0.6326822	-0.484999	1.750363
X	S	0.4170076	-0.751891	1.585907
R	M	0.4131677	-0.308292	1.134628
C	M	0.4082522	-0.012666	0.829170
B	M	0.3280179	-0.213077	0.869113
X	B	0.3046643	-0.804251	1.413579
X	C	0.2244299	-0.831070	1.279930
X	R	0.2195144	-0.987719	1.426748
S	M	0.2156745	-0.439624	0.870973
R	S	0.1974932	-0.601017	0.996003
C	S	0.1925777	-0.349903	0.735058
B	S	0.1123434	-0.527889	0.752576
R	B	0.0851499	-0.622654	0.792953
C	B	0.0802343	-0.316821	0.477290
R	C	0.0049155	-0.615869	0.625700

Difference



Oneway Analysis of 1st Detail 30 Jun - 20 Jul 03 By Recruited Athlete



Missing Rows 4

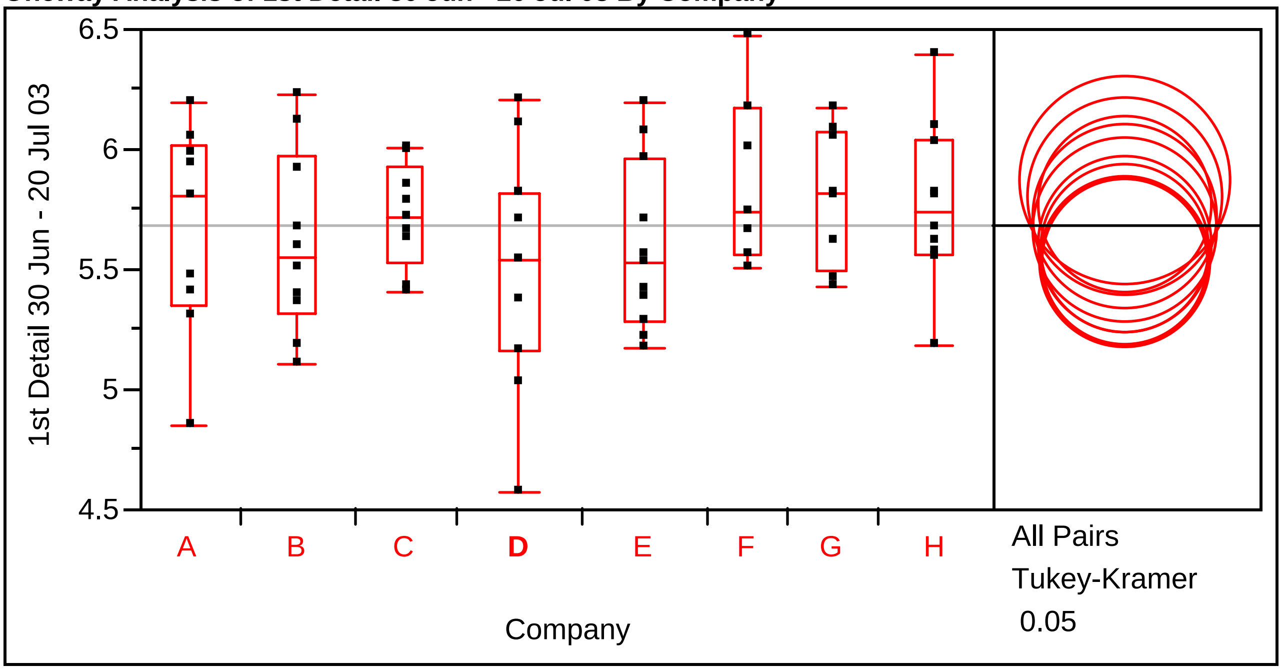
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
1.99308	0.05

Abs(Dif)-LSD	T	F
T	-0.16908	-0.05062
F	-0.05062	-0.16684

Oneway Analysis of 1st Detail 30 Jun - 20 Jul 03 By Company



Missing Rows 4

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.12871	0.05

Abs(Dif)-LSD	F	G	H	C	A	B	E	D
F	-0.61668	-0.52806	-0.46628	-0.42522	-0.37387	-0.30249	-0.27372	-0.21624
G	-0.52806	-0.57685	-0.51402	-0.47345	-0.42210	-0.35023	-0.32103	-0.26355
H	-0.46628	-0.51402	-0.51595	-0.47617	-0.42482	-0.35216	-0.32227	-0.26479
C	-0.42522	-0.47345	-0.47617	-0.54386	-0.49252	-0.42022	-0.39066	-0.33318
A	-0.37387	-0.42210	-0.42482	-0.49252	-0.54386	-0.47157	-0.44200	-0.38452
B	-0.30249	-0.35023	-0.35216	-0.42022	-0.47157	-0.51595	-0.48606	-0.42859
E	-0.27372	-0.32103	-0.32227	-0.39066	-0.44200	-0.48606	-0.49194	-0.43446
D	-0.21624	-0.26355	-0.26479	-0.33318	-0.38452	-0.42859	-0.43446	-0.49194

Level		Mean
F	A	5.8741319
G	A	5.8050885
H	A	5.7718591
C	A	5.7179350
A	A	5.6665902
B	A	5.6080658
E	A	5.5900402
D	A	5.5325620

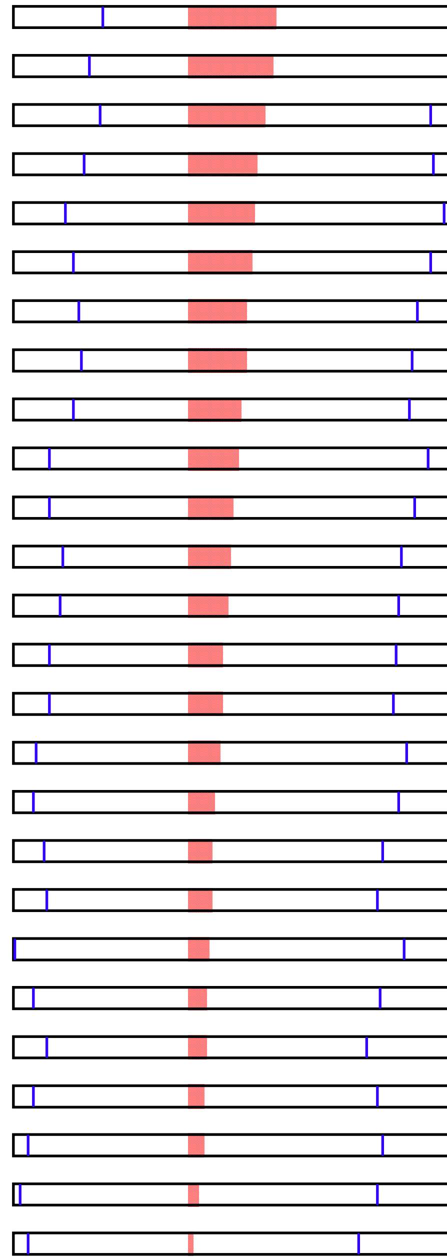
Levels not connected by same letter are significantly different

Level	- Level	Difference	Lower CL	Upper CL	Difference
F	D	0.3415699	-0.216239	0.8993785	
F	E	0.2840917	-	0.8419003	

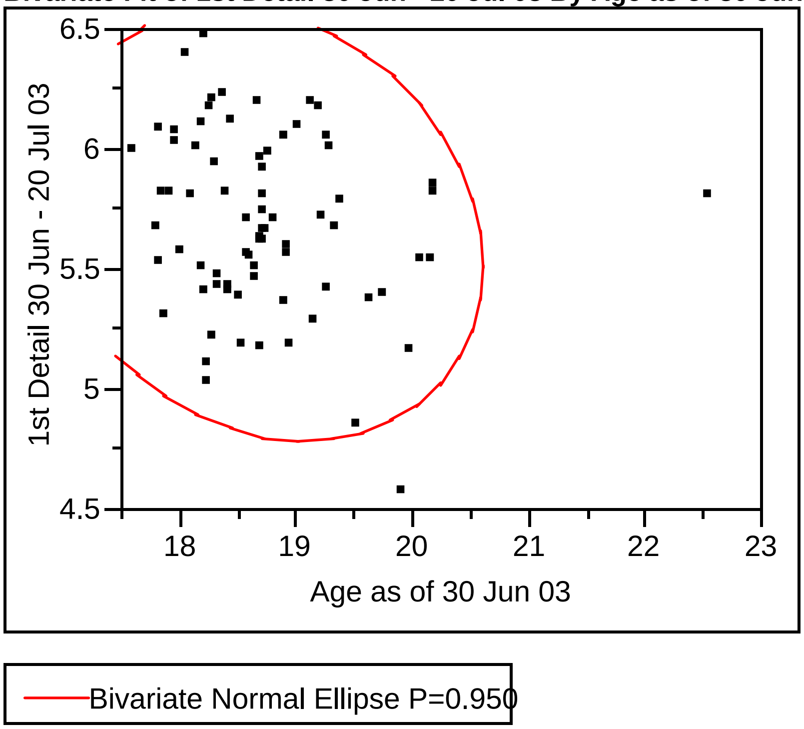
0.273717

Level	- Level	Difference	Lower CL	Upper CL
G	D	0.2725265	-0.263554	0.8086067
F	B	0.2660661	-0.302485	0.8346175
H	D	0.2392971	-0.264792	0.7433866
G	E	0.2150483	-0.321032	0.7511285
F	A	0.2075417	-0.373870	0.7889537
G	B	0.1970227	-0.350227	0.7442724
C	D	0.1853730	-0.333178	0.7039243
H	E	0.1818189	-0.322271	0.6859084
H	B	0.1637933	-0.352159	0.6797453
F	C	0.1561969	-0.425215	0.7376090
G	A	0.1384983	-0.422101	0.6990975
A	D	0.1340283	-0.384523	0.6525795
C	E	0.1278948	-0.390656	0.6464461
C	B	0.1098692	-0.420221	0.6399595
H	A	0.1052688	-0.424821	0.6353591
F	H	0.1022728	-0.466279	0.6708242
G	C	0.0871535	-0.473446	0.6477528
A	E	0.0765501	-0.442001	0.5951014
B	D	0.0755038	-0.428586	0.5795933
F	G	0.0690434	-0.528055	0.6661418
A	B	0.0585245	-0.471566	0.5886147
E	D	0.0574782	-0.434463	0.5494191
H	C	0.0539241	-0.476166	0.5840144
C	A	0.0513447	-0.492516	0.5952059
G	H	0.0332294	-0.514020	0.5804792
B	E	0.0180256	-0.486064	0.5221151

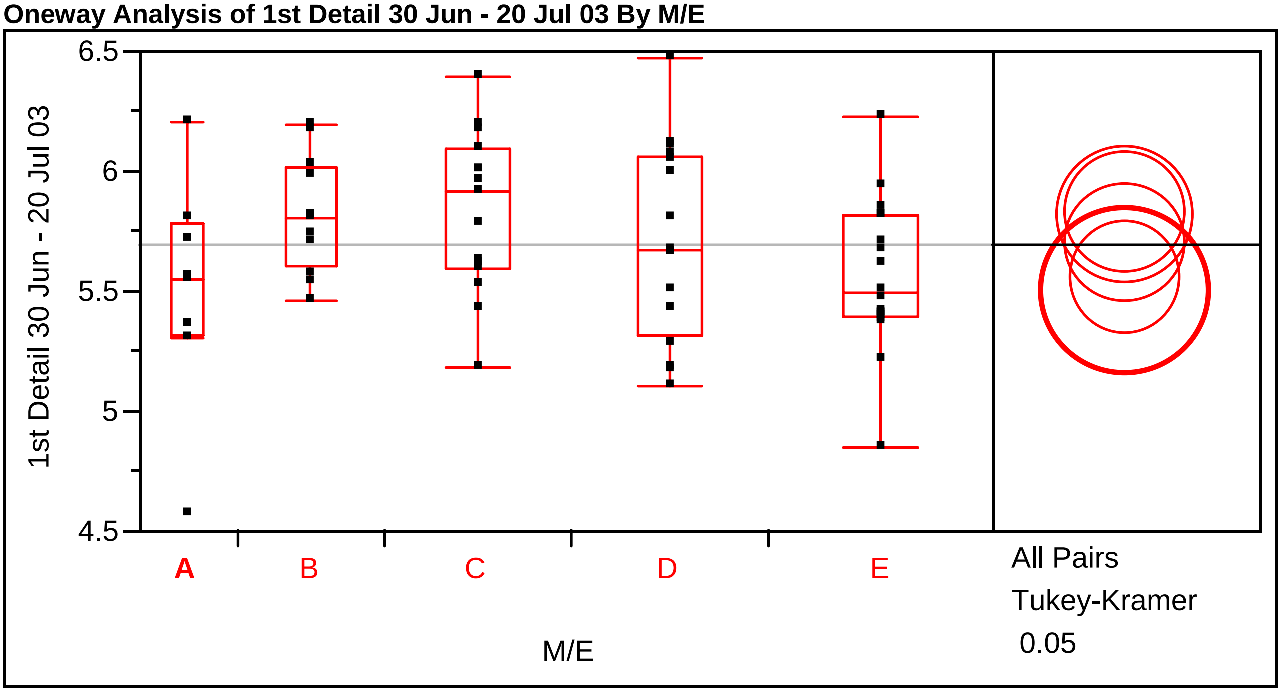
Difference



Bivariate Fit of 1st Detail 30 Jun - 20 Jul 03 By Age as of 30 Jun 03



Oneway Analysis of 1st Detail 30 Jun - 20 Jul 03 By M/E



Missing Rows 10

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.80707	0.05

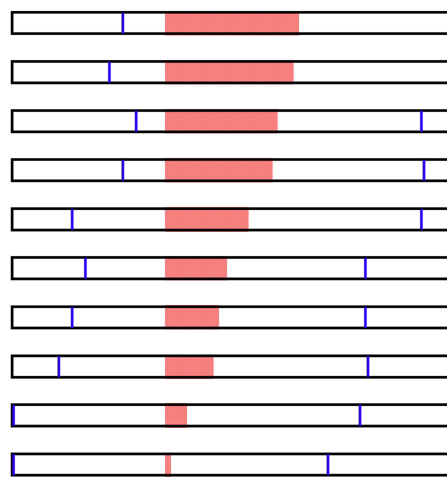
Abs(Dif)-LSD	C	B	D	E	A
C	-0.35890	-0.36734	-0.22532	-0.06961	-0.10490
B	-0.36734	-0.40127	-0.26076	-0.10563	-0.13656
D	-0.22532	-0.26076	-0.34751	-0.19163	-0.22813
E	-0.06961	-0.10563	-0.19163	-0.32763	-0.36626
A	-0.10490	-0.13656	-0.22813	-0.36626	-0.49145

Level		Mean
C	A	5.8332305
B	A	5.8198910
D	A	5.7053005
E	A	5.5592126
A	A	5.5078199

Levels not connected by same letter are significantly different

Level	- Level	Difference	Lower CL	Upper CL
C	A	0.3254106	-0.104901	0.7557221
B	A	0.3120711	-0.136560	0.7607019
C	E	0.2740179	-0.069607	0.6176429
B	E	0.2606784	-0.105627	0.6269839
D	A	0.1974806	-0.228128	0.6230891
D	E	0.1460878	-0.191629	0.4838049
C	D	0.1279300	-0.225322	0.4811823
B	D	0.1145906	-0.260761	0.4899420
E	A	0.0513927	-0.366260	0.4690453
C	B	0.0133395	-0.367336	0.3940153

Difference

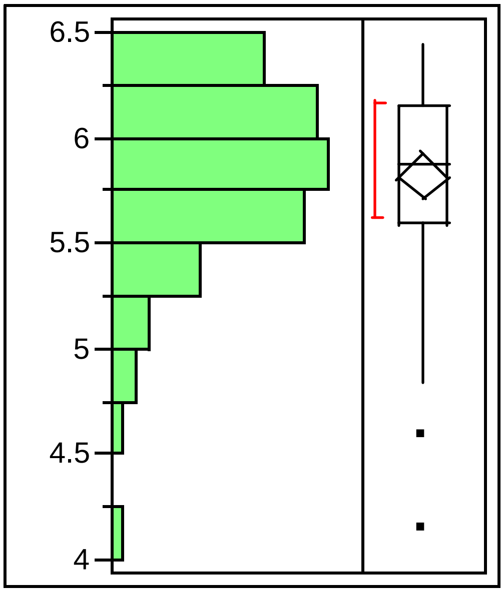


2nd Detail (21 Jul – 5 Aug 03) Distribution and Box Plots

Note: 2nd Detail Analysis stops on March-out Day to Lake Frederick

Distributions

2nd Detail 21 Jul - 5 Aug 03



Quantiles

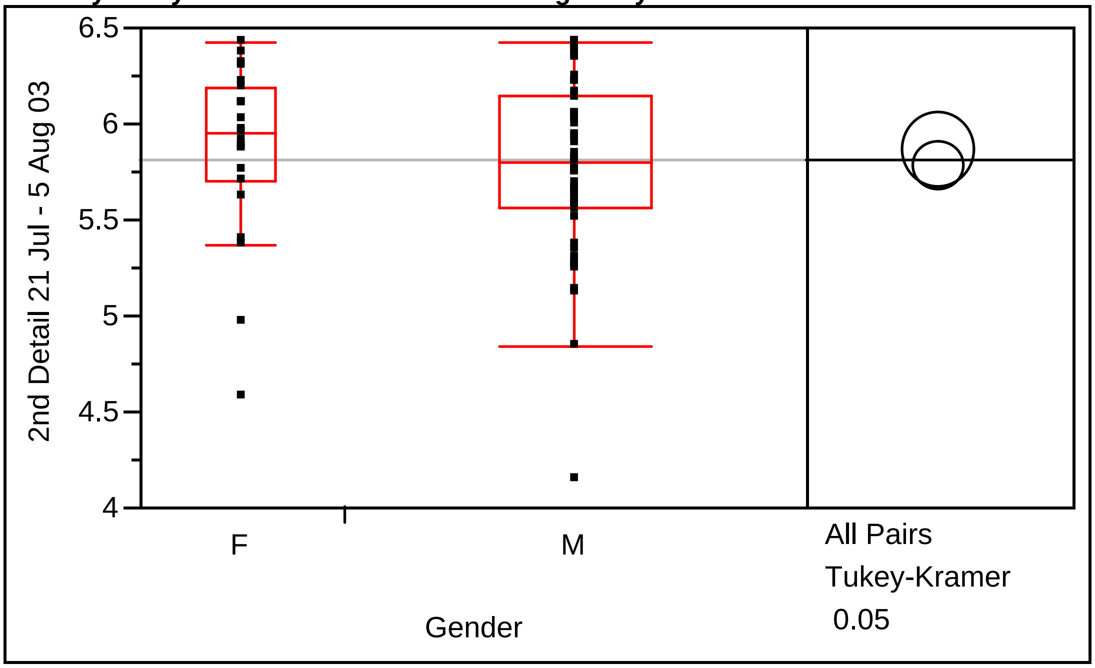
100.0%	maximum	6.4281
99.5%		6.4281
97.5%		6.4230
90.0%		6.3766
75.0%	quartile	6.1502
50.0%	median	5.8703
25.0%	quartile	5.5869
10.0%		5.2526
2.5%		4.5276
0.5%		4.1448
0.0%	minimum	4.1448

Moments

Mean	5.8113545
Std Dev	0.4542179
Std Err Mean	0.0528018
upper 95% Mean	5.9165882
lower 95% Mean	5.7061207
N	74

Fit Y by X Group

Oneway Analysis of 2nd Detail 21 Jul - 5 Aug 03 By Gender



Missing Rows 5

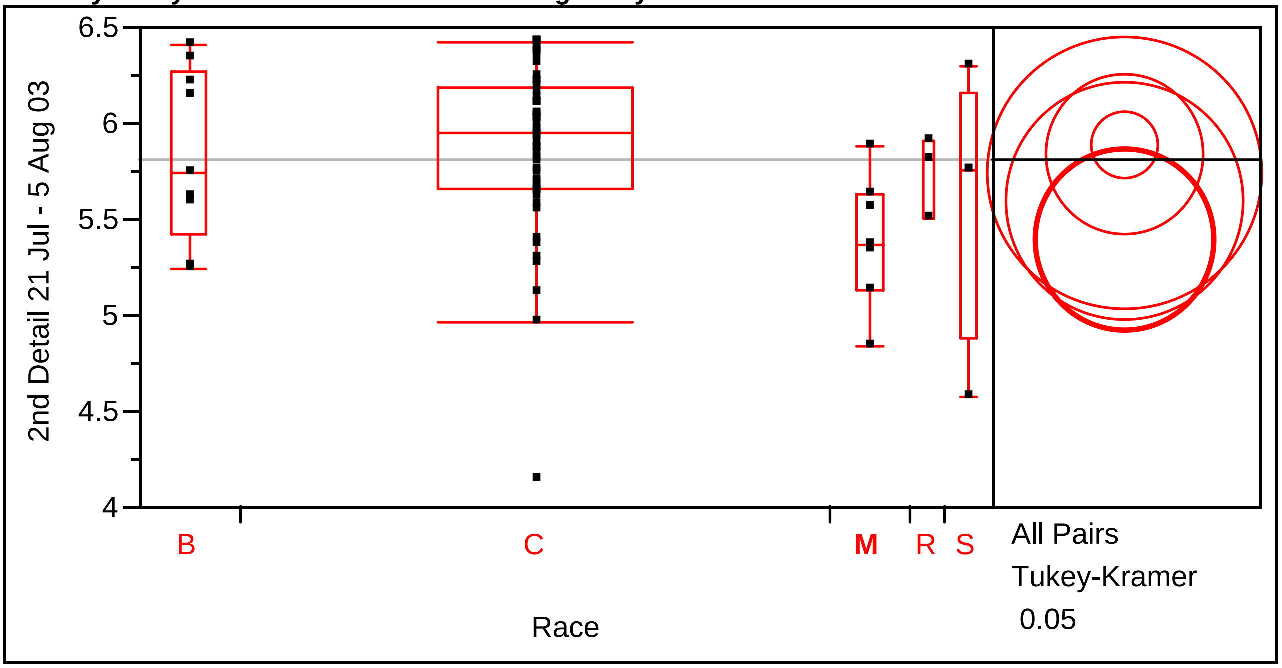
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha	
1.99354	0.05	

Abs(Dif)-LSD	F	M
F	-0.26795	-0.14768
M	-0.14768	-0.17994

Oneway Analysis of 2nd Detail 21 Jul - 5 Aug 03 By Race



Missing Rows 5

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.80122	0.05

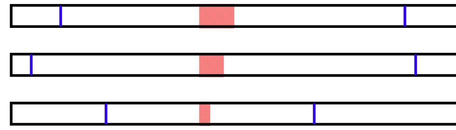
Abs(Dif)-LSD	C	B	R	S	M
C	-0.2443	-0.4007	-0.5902	-0.3546	-0.0088
B	-0.4007	-0.5815	-0.7250	-0.5006	-0.1785
R	-0.5902	-0.7250	-1.0071	-0.7988	-0.5054
S	-0.3546	-0.5006	-0.7988	-0.8722	-0.5706
M	-0.0088	-0.1785	-0.5054	-0.5706	-0.6593

Level		Mean
C	A	5.8842960
B	A	5.8390201
R	A	5.7416667
S	A	5.5984375
M	A	5.3958863

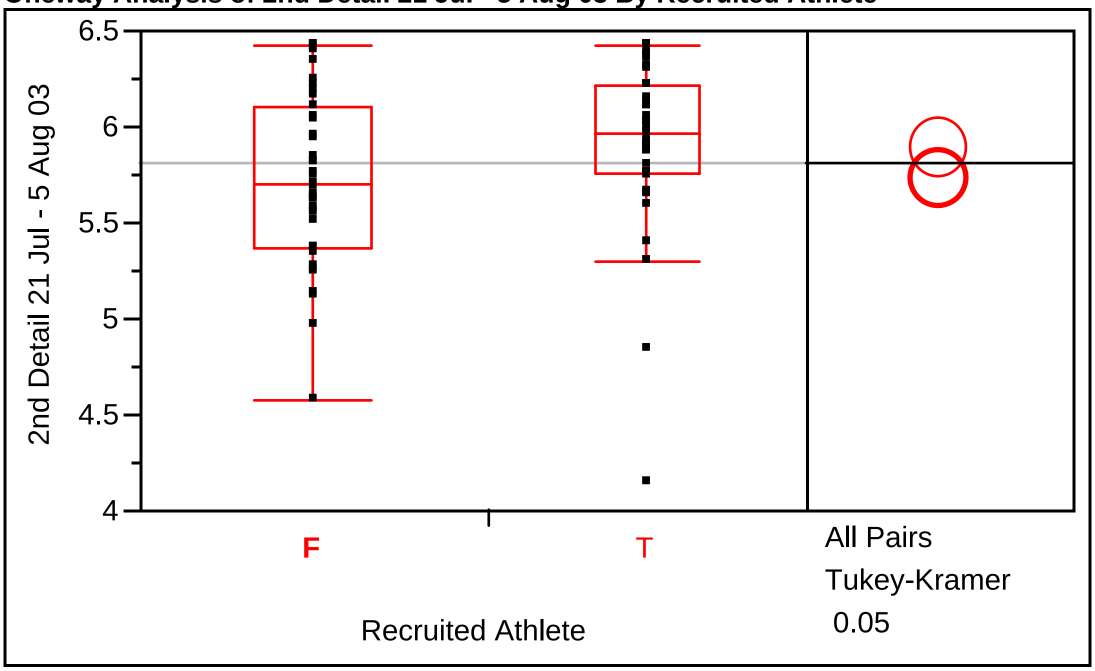
Levels not connected by same letter are significantly different

Level	- Level	Difference	Lower CL	Upper CL	Difference
C	M	0.4884097	-0.008762	0.985581	
B	M	0.4431337	-0.178473	1.064741	
R	M	0.3457804	-0.505390	1.196951	
C	S	0.2858585	-0.354602	0.926319	
B	S	0.2405826	-0.500637	0.981802	
S	M	0.2025512	-0.570563	0.975665	
R	S	0.1432292	-	1.085302	

Level	- Level	Difference	Lower CL	Upper CL	Difference
			0.798844		
C	R	0.1426294	-0.590157	0.875416	
B	R	0.0973534	-0.724956	0.919662	
C	B	0.0452760	-0.400684	0.491236	



Oneway Analysis of 2nd Detail 21 Jul - 5 Aug 03 By Recruited Athlete



Missing Rows 5

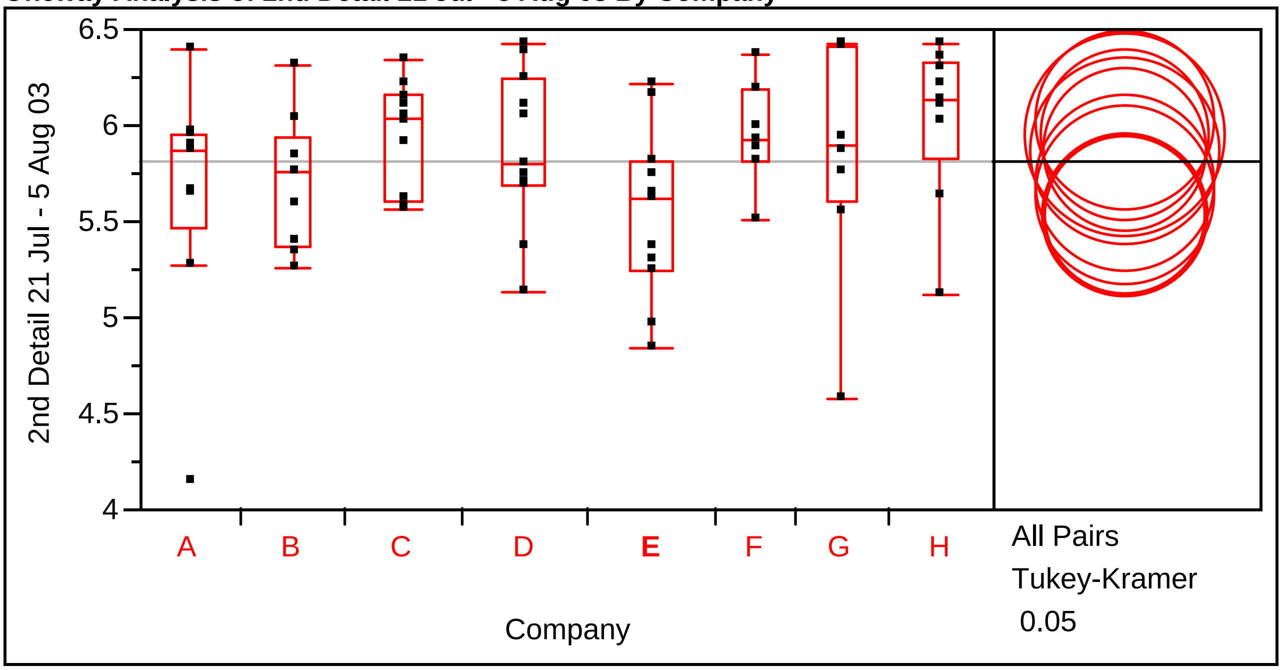
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
1.99354	0.05

Abs(Dif)-LSD	T	F
T	-0.21420	-0.04168
F	-0.04168	-0.20292

Oneway Analysis of 2nd Detail 21 Jul - 5 Aug 03 By Company



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Means Comparisons

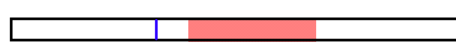
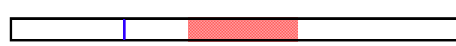
Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
3.13022	0.05

Abs(Dif)-LSD	H	F	C	D	G	B	A	E
H	-0.65553	-0.62432	-0.56022	-0.46776	-0.51339	-0.32546	-0.26835	-0.13105
F	-0.62432	-0.74330	-0.68304	-0.59154	-0.63385	-0.44718	-0.39008	-0.25483
C	-0.56022	-0.68304	-0.62189	-0.52904	-0.57601	-0.38757	-0.33047	-0.19233
D	-0.46776	-0.59154	-0.52904	-0.59295	-0.64110	-0.45221	-0.39511	-0.25624
G	-0.51339	-0.63385	-0.57601	-0.64110	-0.69529	-0.50794	-0.45084	-0.31449
B	-0.32546	-0.44718	-0.38757	-0.45221	-0.50794	-0.65553	-0.59842	-0.46112
A	-0.26835	-0.39008	-0.33047	-0.39511	-0.45084	-0.59842	-0.65553	-0.51822
E	-0.13105	-0.25483	-0.19233	-0.25624	-0.31449	-0.46112	-0.51822	-0.59295

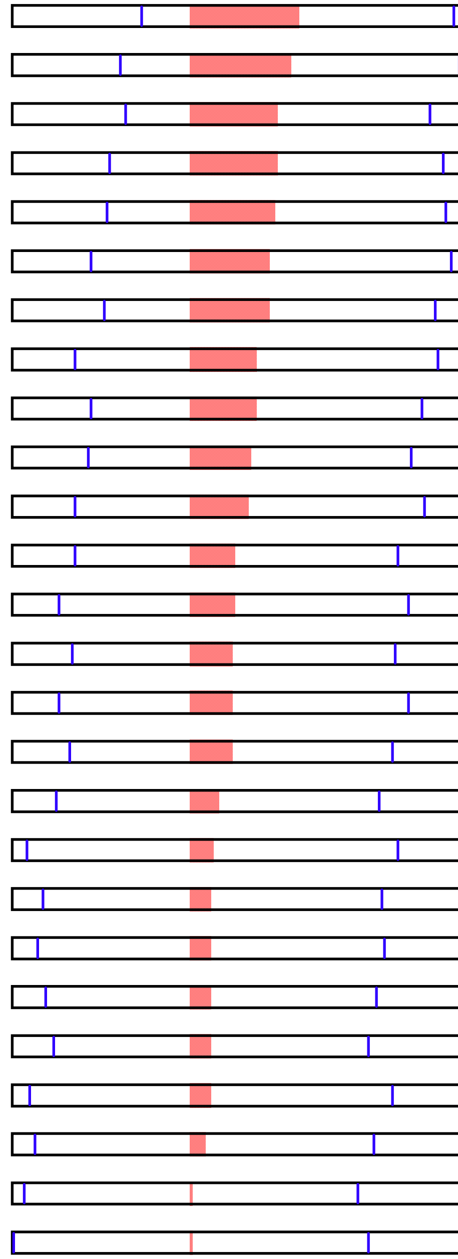
Level		Mean
H	A	6.0308102
F	A	5.9543452
C	A	5.9520972
D	A	5.8735453
G	A	5.8684983
B	A	5.7007390
A	A	5.6436343
E	A	5.5368371

Levels not connected by same letter are significantly different

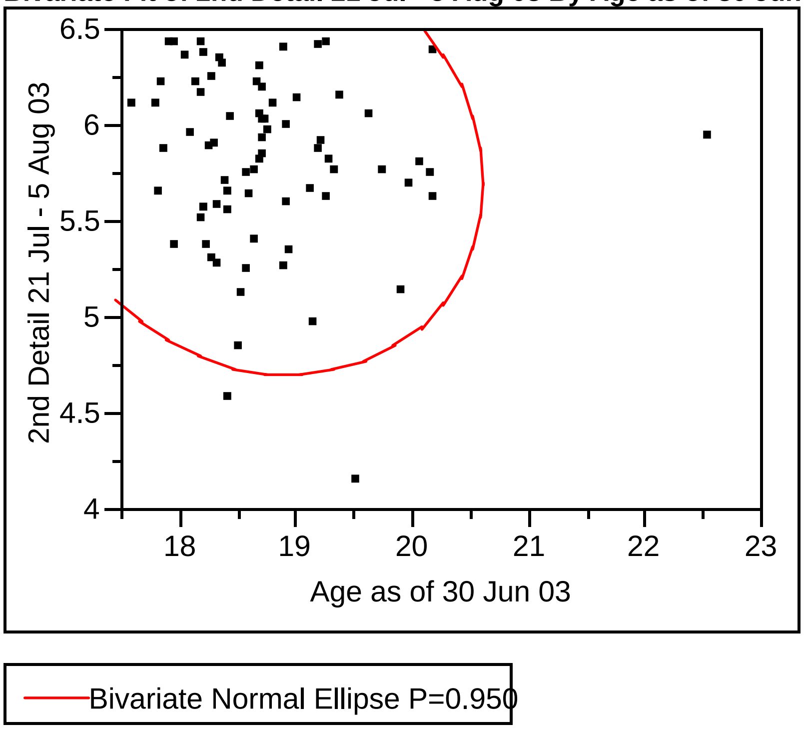
Level	- Level	Difference	Lower CL	Upper CL	Difference
H	E	0.4939731	-0.131047	1.118994	
F	E	0.4175081	-	1.089846	

0.254830

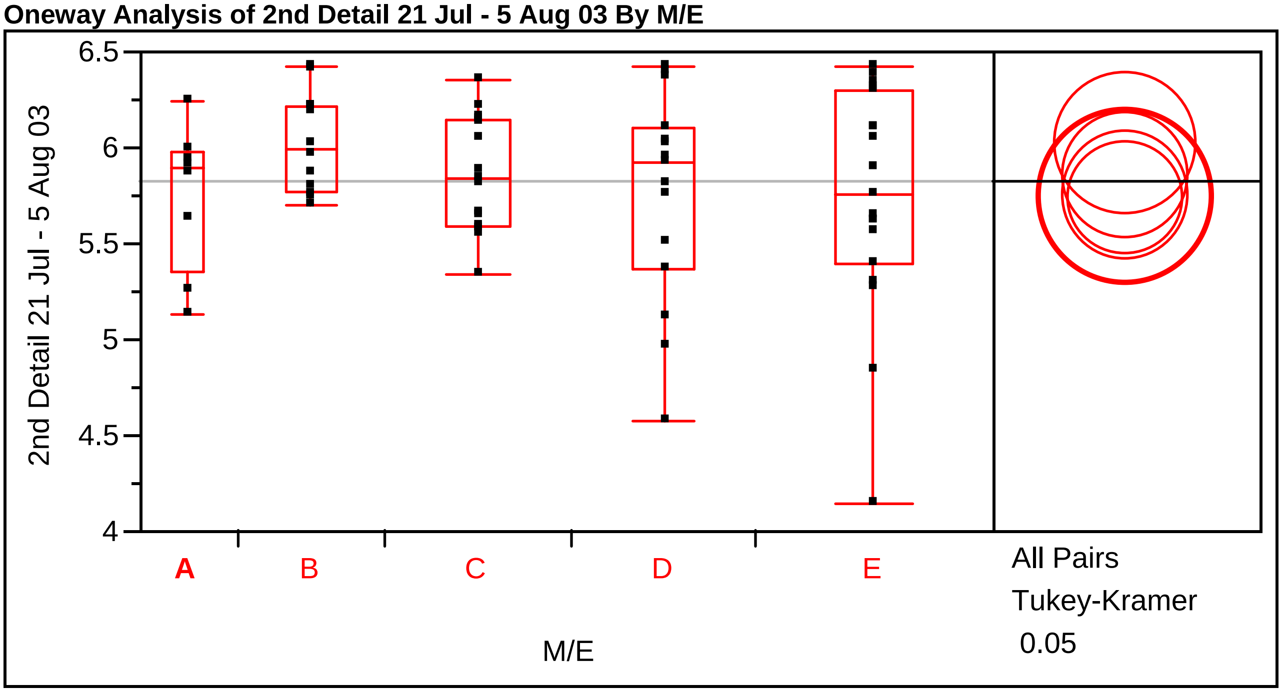
Level	- Level	Difference	Lower CL	Upper CL	Difference
C	E	0.4152601	-0.192329	1.022850	
H	A	0.3871759	-0.268351	1.042703	
D	E	0.3367082	-0.256238	0.929655	
G	E	0.3316611	-0.314487	0.977810	
H	B	0.3300712	-0.325456	0.985598	
F	A	0.3107110	-0.390077	1.011499	
C	A	0.3084630	-0.330466	0.947392	
F	B	0.2536063	-0.447182	0.954394	
C	B	0.2513583	-0.387571	0.890287	
D	A	0.2299110	-0.395110	0.854932	
G	A	0.2248640	-0.450838	0.900566	
D	B	0.1728063	-0.452214	0.797827	
G	B	0.1677593	-0.507943	0.843461	
B	E	0.1639018	-0.461119	0.788922	
H	G	0.1623119	-0.513390	0.838014	
H	D	0.1572649	-0.467756	0.782285	
A	E	0.1067971	-0.518223	0.731818	
F	G	0.0858470	-0.633848	0.805542	
C	G	0.0835990	-0.576012	0.743210	
F	D	0.0808000	-0.591538	0.753138	
H	C	0.0787130	-0.560216	0.717642	
C	D	0.0785519	-0.529037	0.686141	
H	F	0.0764649	-0.624323	0.777253	
B	A	0.0571047	-0.598422	0.712632	
D	G	0.0050470	-0.641102	0.651196	
F	C	0.0022480	-0.683039	0.687535	



Bivariate Fit of 2nd Detail 21 Jul - 5 Aug 03 By Age as of 30 Jun 03



Oneway Analysis of 2nd Detail 21 Jul - 5 Aug 03 By M/E



Missing Rows 10

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.80707	0.05

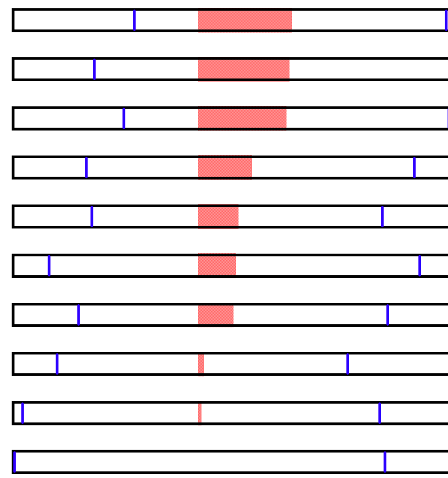
Abs(Dif)-LSD	B	C	D	A	E
B	-	-	-	-	-

	q*	Alpha				
		0.52431	0.33647	0.22891	0.31140	0.18967
C		-	-	-	-	-
		0.33647	0.46895	0.36139	0.44839	0.32062
D		-	-	-	-	-
		0.22891	0.36139	0.46895	0.55595	0.42818
A		-	-	-	-	-
		0.31140	0.44839	0.55595	0.64214	0.53217
E		-	-	-	-	-
		0.18967	0.32062	0.42818	0.53217	0.41668

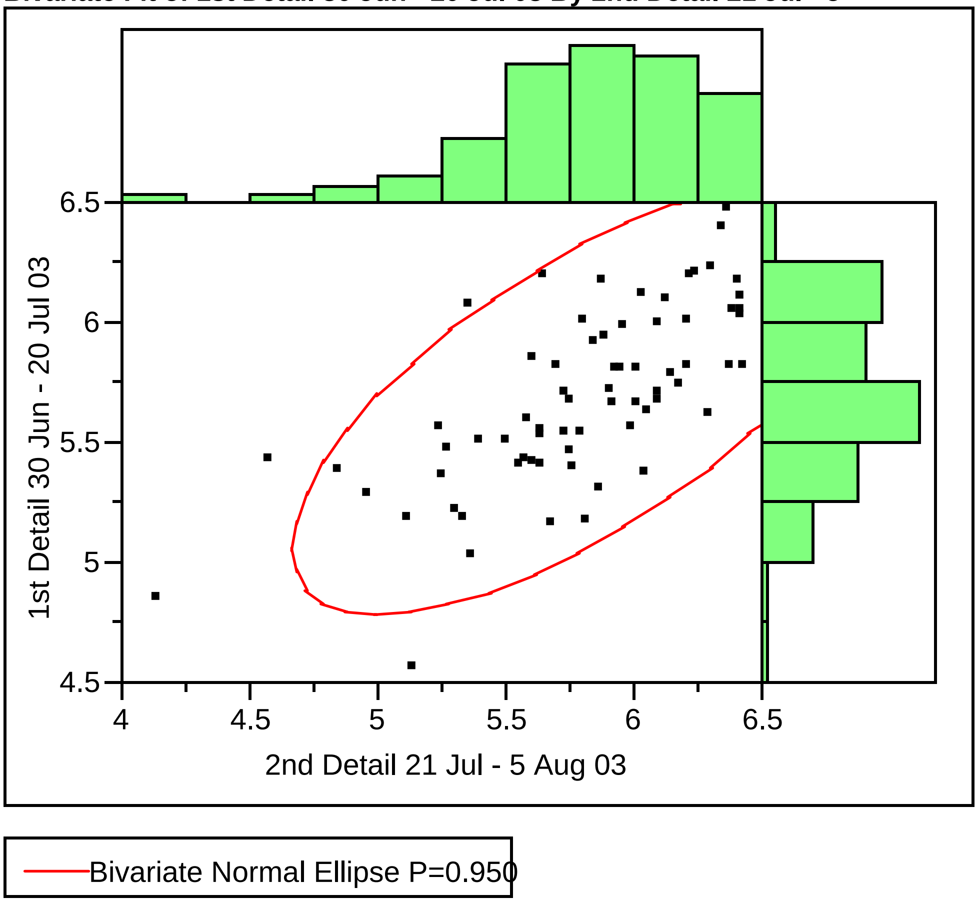
Level		Mean
B	A	6.0235590
C	A	5.8626332
D	A	5.7550741
A	A	5.7487723
E	A	5.7396674

Levels not connected by same letter are significantly different

Level	- Level	Difference	Lower CL	Upper CL	Difference
B	E	0.2838916	-0.189666	0.7574497	
B	A	0.2747867	-0.311404	0.8609778	
B	D	0.2684850	-0.228915	0.7658846	
B	C	0.1609258	-0.336474	0.6583255	
C	E	0.1229658	-0.320619	0.5665508	
C	A	0.1138609	-0.448394	0.6761156	
C	D	0.1075591	-0.361394	0.5765120	
D	E	0.0154067	-0.428178	0.4589917	
A	E	0.0091049	-0.532173	0.5503824	
D	A	0.0063018	-0.555953	0.5685565	



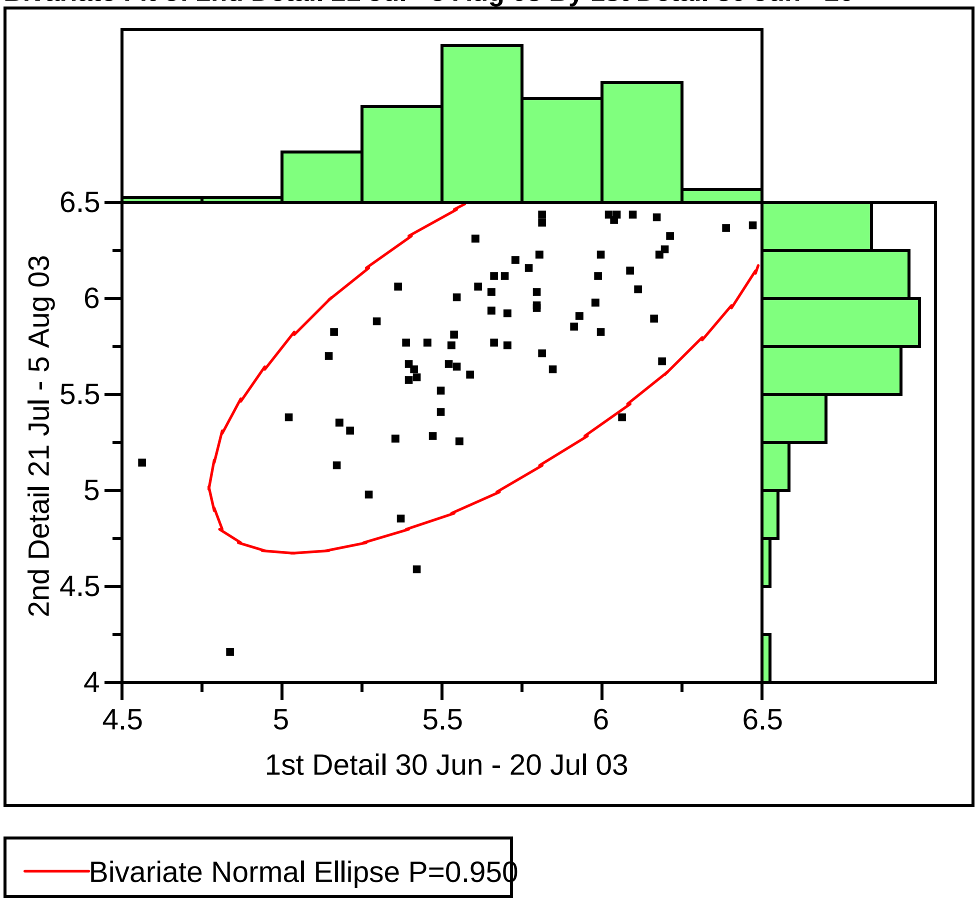
Bivariate Fit of 1st Detail 30 Jun - 20 Jul 03 By 2nd Detail 21 Jul - 5



Correlation

Variable	Mean	Std Dev	Correlation	Signif. Prob	Number
2nd Detail 21 Jul - 5 Aug 03	5.801926	0.459806	0.701641	0.0000	70
1st Detail 30 Jun - 20 Jul 03	5.683498	0.368848			

Bivariate Fit of 2nd Detail 21 Jul - 5 Aug 03 By 1st Detail 30 Jun - 20



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